Engineers Australia

Engineering Heritage Victoria

Nomination

Engineering Heritage Australia Heritage Recognition Program

JINDALEE

OVER-THE-HORIZON RADAR

MAY 2016

Front Cover Photograph Caption

Jindalee transmitter array at Longreach in Queensland. Sunsets in the Outback are often spectacular and this image is no exception. This transmitter station is 119 km north east of the receiver station at Stonehenge and 26 km South West of the town of Longreach.

Image: Department of Defence.

TABLE OF CONTENTS

1 Introduction [1]

Jindalee is an aboriginal word for a place [the] eye cannot see, or somewhere beyond where the eye can see, like over the horizon [2].

The original project to develop an over-the-horizon radar in Australia was called **Jindalee** and the operational outcome of that project called **JORN** [3] continues the use of the iconic name **Jindalee.**

"To me, the JORN system is one of Australia's quietest achievers. It is an astounding system, the most capable radar network in the world, all Australian designed and built, and should be acknowledged as one of Australia's finest defence technology achievements" [4].

As the CEO of Power and Water Authority in the Northern Territory in the1990s I visited the **Jindalee** site at Mount Everard north of Alice Springs. The facility was an electricity customer of Power and Water which gave me some 'key supplier' rights which I used to try to satisfy my curiosity about the 'magic' of the **Jindalee** system. For many people, even engineers with a broad technical knowledge, **Jindalee** was always, and still is, a mixture of technology and magic.

Two incidents during my visits convinced me that there really was some magic in the **Jindalee** technology. They are worth relating here:

In the control room I was looking over the shoulder of a young operator who obviously has immense regard for the system. He said "look at this" as an image appeared on the monitor "I can tell you that that is a Boeing 747 taking off from Changi Airport in Singapore but unfortunately I can't tell you which airline owns it". Singapore is 4100 km from Alice Springs as the crow flies!

On another visit the operator told of an incident which happened over Papua New Guinea. The RAAF was aware of a test flight around the world of the US Air Force F-117 Nighthawk stealth attack aircraft [5]. The idea was that the US Air Force would fly the aircraft roughly around the Equator just to prove that nobody could see it on radar. The operator told me that they picked up the aircraft over New Guinea and reported the sighting to the US Air Force. The Americans were flabbergasted but they knew that the reported location of the aircraft was exactly where the aircraft was

---

[1] Part of this Introduction is written in the first person. As the author of this nomination I, Owen Peake, took the decision to use first person in the Introduction to assist the development of the story. My author details are at page 35 of this document.

[2] Jindalee Weather Poole Dorset England. Page last updated Thursday 14 April 2016. http://jindaleeweather.co.uk

[3] JORN = Jindalee Operational Radar Network. JORN therefore refers to the three Jindalee stations (Alice Springs NT, Laverton, WA and Longreach, Queensland).

[4] MinMiester. Aviation forums, Modern Military Aviation, JORN.Key Publishing Ltd.9 February 2001.

[5] The F-117 Nighthawk was manufactured by Lockheed Martin and went into service in 1983. It is best known for its role in the 1991 Gulf War. 64 aircraft were built. Although notionally now out of service it is understood that the USAF continues to operate some of these aircraft.

at that time. The aircraft had, of course, been designed to be radar-transparent from ground or airborne radar operating in the Microwave range but **Jindalee** was looking down on it from the ionosphere and **Jindalee** operates in the very different HF (High Frequency) range.

Lockheed Martin F-117 Nighthawk. Not so stealthy to Jindalee. ***Image: Wikipedia.***

There are so many superlatives around this project that it is difficult to know when to stop. Here is just one more mind–blowing fact about **JORN**. The **JORN** system (the three stations which constitute **JORN**) can detect aircraft and ships over an area of approximately 13 million square kilometres [6]. That is more than 1.7 times the total land area of Australia! [7]

[6] Calculation by Owen Peake based on a range of 1000 to 3000 km from the receiver station and the net areas within the range of the three stations i.e. it is the area of the coloured sections on the map at page 11.
[7] The area of Australia is taken as 7.692 million square kilometres.

2 Heritage Award Nomination Letter

Learned Society Advisor
Engineering Heritage Australia
Engineers Australia
Engineering House
11 National Circuit
BARTON ACT 2600

Name of work: Jindalee Over-the-horizon Radar

The above-mentioned work is nominated to be recognised under the Heritage Recognition Program.

There are three radar stations in the network located at Alice Springs NT, Laverton, WA and Longreach, Queensland). There is also a Communications Centre located at the Edinburgh Air Force Base in South Australia.

Grid reference of the radar stations are:

- **Longreach, Queensland** with 90 degree coverage. Transmitter Station **23.658047°S 144.145432°E** and Receiver Station at **Stonehenge** with 90 degree coverage **24.291095°S 143.195286°E.**
- **Leonora, Western Australian** Transmitter Station at **Leonora** with 180 degree coverage **28.317378°S 122.843456°E** and Receiver Station at **Laverton** with 180 degree coverage **28.326747°S 122.005234°E.**
- **Alice Springs, Northern Territory** is the location of the research and development transmitter and receiver sites. The Transmitter Station at **Harts Range** with 90 degree coverage **22.967561°S 134.447937°E** and the Receiver Station at **Mount Everard** with 90 degree coverage **23.521497°S 133.677521°E.**

The owner of the system is the Commonwealth Government via the Royal Australian Air Force and Defence Science and Technology Group.

Access to site: The sites are operational defence bases and are subject to strict security protocols. The sites are therefore not open to the public.

The Nominating Body for this nomination is Engineering Heritage Northern.

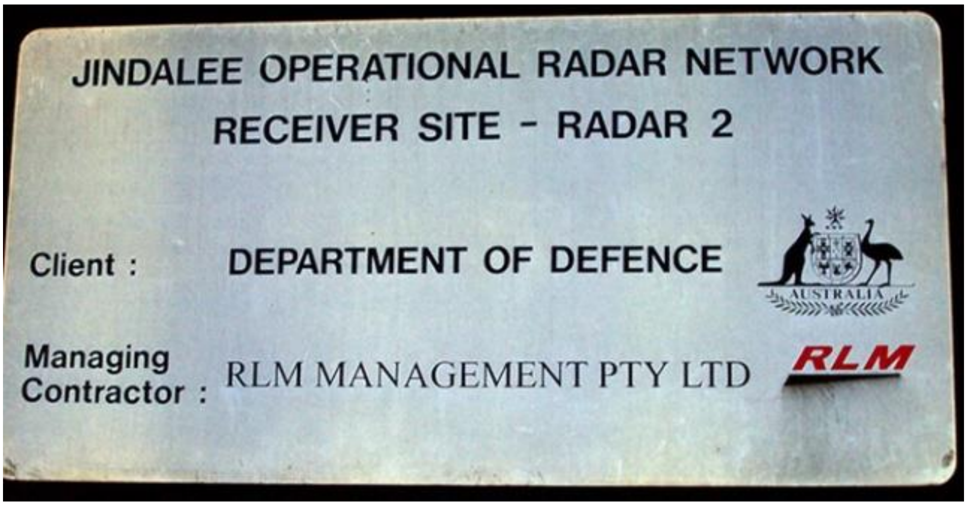
Trevor C Horman
Chair
Engineering Heritage Northern

Date: May 2016

3 Heritage Assessment

3.1 Basic Data

Other/Former Names: The term **Jindalee** is used primarily in reference to the technology whilst the term **JORN** (Jindalee Operational Radar Network) is applicable to the operational functions of the system. Signs relating to the sites are likely to be rather bland.



This sign is beside the road near the Laverton Receiver site.
Image: http://onthetrailofharrymason.weebly.

Location: The JORN project consists of [8]:

- two active radar stations: one near **Longreach, Queensland (JOR1)** and a second near **Laverton, Western Australia (JOR2)** with **Alice Springs** as a backup.
- a control centre at **RAAF Edinburgh in South Australia (JCC)**
- seven transponders
- twelve vertical ionosondes distributed around Australia and its territories [9].

DSTO uses a radar station at **Mount Everard near Alice Springs, Northern Territory (JFAS)** for research and development [10] and also has its own network of

[8] Chlanda Erwin. Nowhere to Hide When Alice's Radar Zeroes In. Alice Springs News. 28 April 2004.
[9] Colegrove Samuel B (Bren). "Project Jindalee: From Bare Bones To Operational OTHR" (PDF). IEEE International Radar Conference - Proceedings. IEEE. pp. 825–830. 2000. Retrieved 17 November 2006.
[10] Wise John C. "Summary of recent Australian radar developments" (PDF). IEEE A&E Systems Magazine (IEEE) (4): 8–10. December 2004. Retrieved 29 -11-2006.

vertical/oblique ionosondes for research purposes [11] [12] [13]. The Alice Springs radar can be patched into the **JORN** to provide a third active radar station.

Each radar station consists of a transmitter site and a receiver site, separated by approximately 100 km to prevent the transmitter from interfering with the receiver. The four **JORN** transmitter and receiver sites are:

- **Longreach, Queensland** with 90 degree coverage. Transmitter Station **23.658047°S 144.145432°E** and Receiver Station at **Stonehenge** with 90 degree coverage **24.291095°S 143.195286°E.**
- **Leonora, Western Australian** Transmitter Station at **Leonora** with 180 degree coverage **28.317378°S 122.843456°E** and Receiver Station at **Laverton** with 180 degree coverage **28.326747°S 122.005234°E.**
- **Alice Springs, Northern Territory** is the location of the research and development transmitter and receiver sites. The Transmitter Station at **Harts Range** with 90 degree coverage **22.967561°S 134.447937°E** and the Receiver Station at **Mount Everard** with 90 degree coverage **23.521497°S 133.677521°E.**

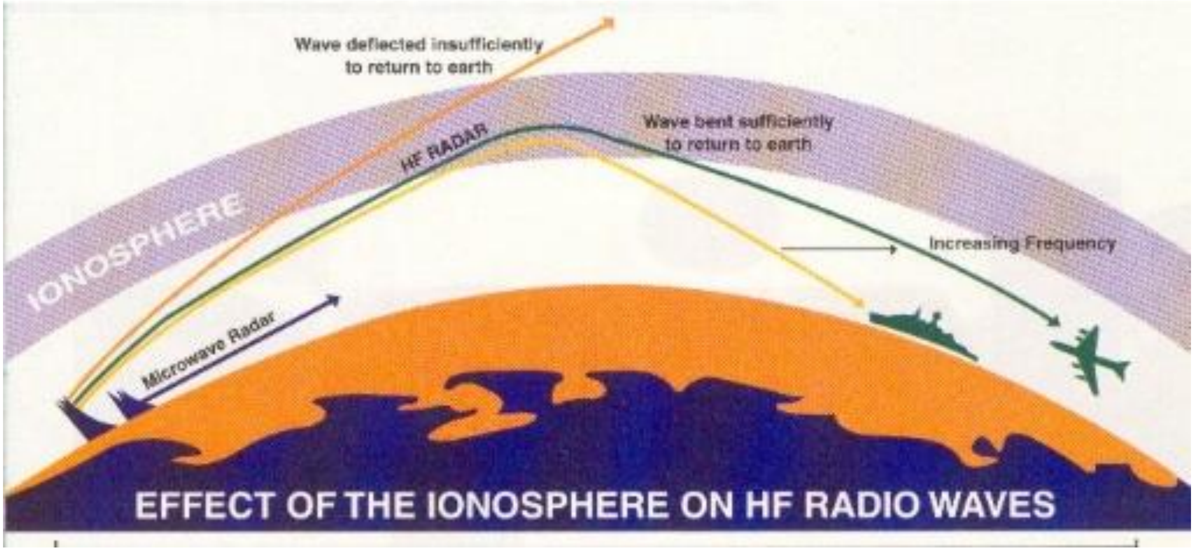
Address: Suburb/Nearest Town: Alice Springs, NT; Laverton, WA and Longreach, Queensland.
States: Northern Territory, Western Australia and Queensland.
Local Govt. Area: not applicable.
Owner: The owner of the system is the Commonwealth Government via the Royal Australian Air Force and Defence Science and Technology Group, previously Defence Science and Technology Organisation.
Current Use: Operational defence radar station.
Former Use: Research into over-the-horizon radar in the case of the Alice Springs base.
Designer: Defence Science and Technology Organisation (DSTO)
Maker/Builder: Defence Science and Technology Organisation (DSTO) built many components in-house and purchased other components from various contractors for use in the system or for modification.
Year Started: 1970
Year Completed: On 2 April 2003 [14] the **JORN** system of Longreach and Laverton stations was officially handed over to the Royal Australian Air Force and became operational. However the development of OTHR is never completed as the technology continues to

[11] "Digisonde Station List". University of Massachusetts Lowell, Center for Atmospheric Research. February 2004. Retrieved 29-11-2006.
[12] Gardiner-Garden R S. "Ionospheric variability in sounding data from JORN". Workshop on the Applications of Radio Science (WARS), Leura, NSW. February 2006. Retrieved 29-11-2006.
[13] Colegrove Samuel B (Bren). "Project Jindalee: From Bare Bones To Operational OTHR" (PDF). IEEE International Radar Conference - Proceedings. IEEE. pp. 825–830. 2000. Retrieved 17 November 2006.

[14] Liu Bin-Yi. HF Over-the-horizon Radar System Performance Analysis. Naval Postgraduate School, Monterey, California, United States of America. September 2007. Thesis.

advance, providing additional range, more detailed returned signals information and new features.

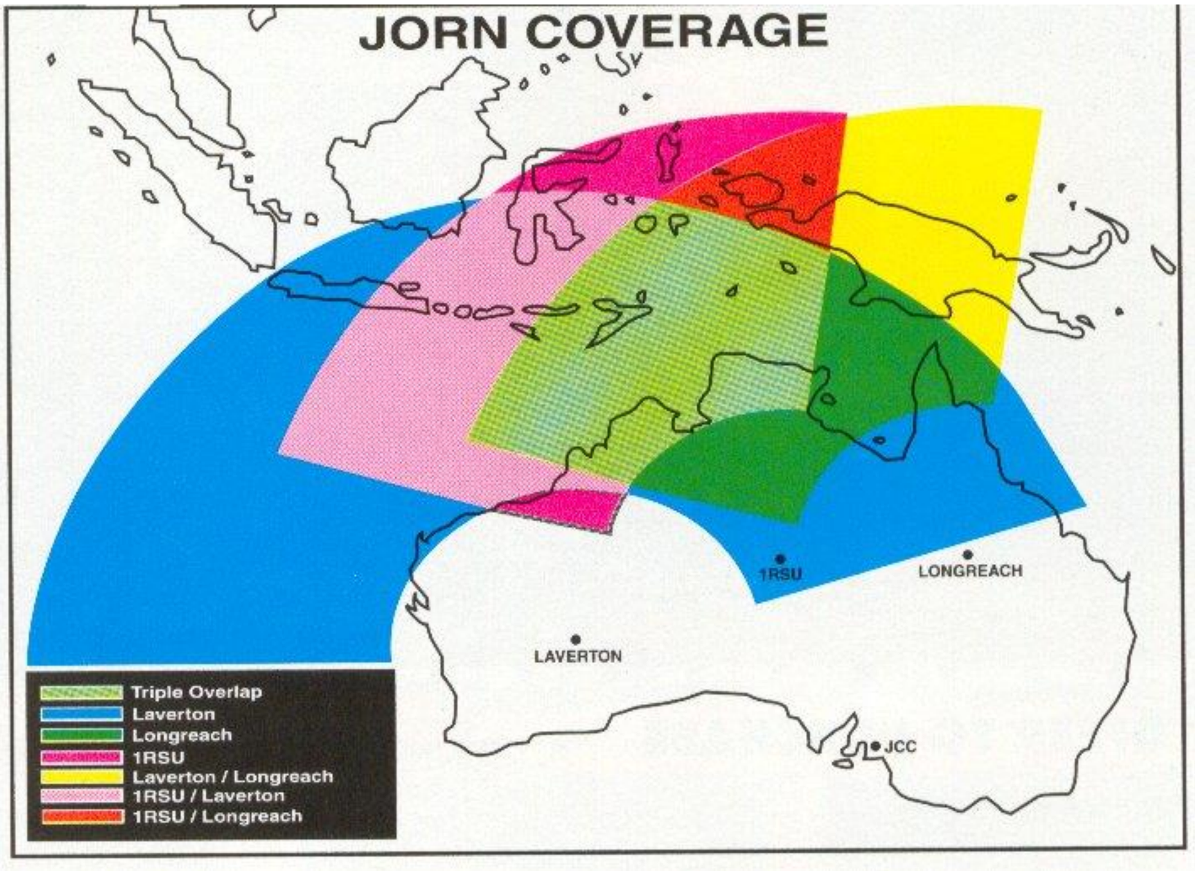
Physical Description: The **Jindalee** system depends on the concept of bouncing HF [15] radar signals off the Ionosphere to achieve extreme range (over-the horizon) and collecting return signals by the same method. This is illustrated in the diagram below.



The principle of OTHR. *Image: Key Publications Ltd, Aviation Forum.*

There are three radar stations in the network, each consisting of a separate transmitter and receiver separated by some hundreds of kilometres. This ensures that there is no interference between outgoing and incoming signals. The radar stations are located near Alice Springs (1RSU), Laverton and Longreach. There is a Control Centre at RAAF Edinburgh in South Australia termed (JCC). See below map for locations.

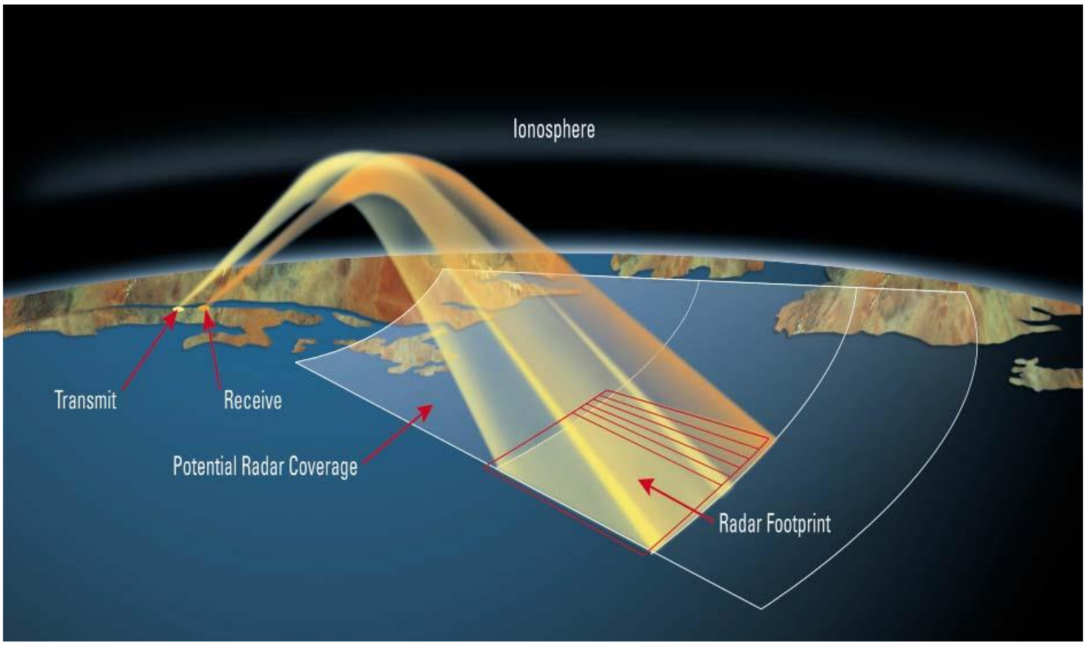
[15] HF (High Frequency) is that portion of the electromagnetic spectrum, designated by the International Telecommunications Union (ITU), between 3 and 30 MHz. It is sometimes referred to as the Decameter Band.



Locations of the JORN Radar Stations and the areas covered based on a nominal range of 3000 km. *Image: Key Publications Ltd Aviation Forum.*

The radars bounce their outgoing signals off the bottom to the ionosphere which reflects the signal to the target. The return signal follows a similar path in reverse. On receiving the return signal at the receiver station the data is converted to digital format and processed to provide a useful image of the target. The processing requires very powerful computers and complex software.

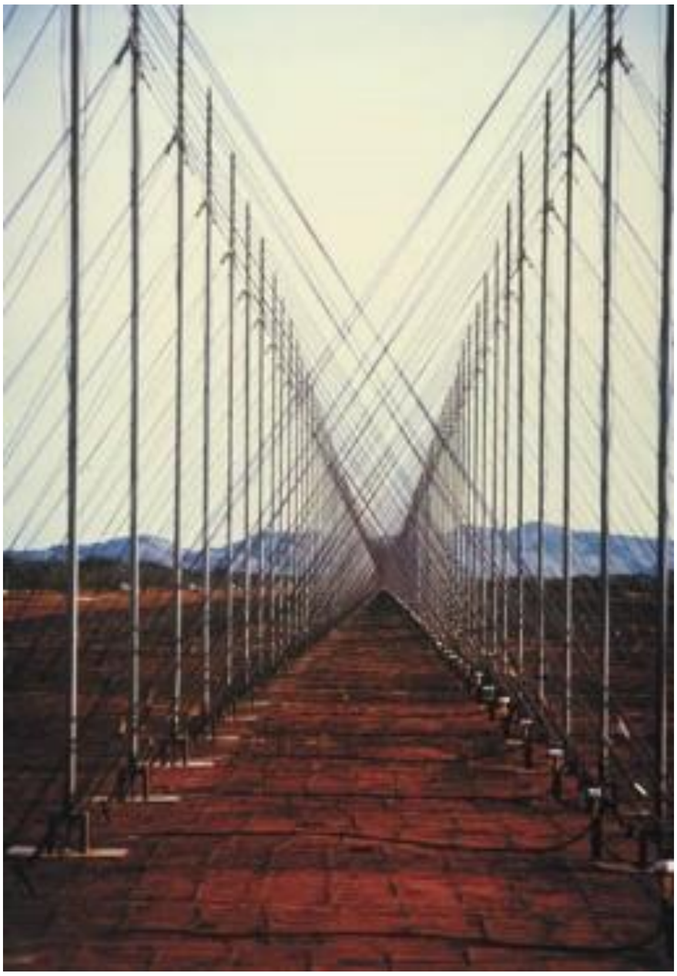
The radars can be aimed at any particular location where a search is required. This area is termed a ‘search box’. The OTHR radar does not scan like a conventional radar but is directed to the area of interest by the operators. This mechanism is illustrated in the graphic below.



Aiming the radars at a particular 'search box'. *Image: RAAF*

Each receiver site has a very large and complex antenna array. The two images below show the antenna arrays at Laverton and Alice Springs.

CAND98/0153-25
JORN PROJECT RECEIVER SITE ANTENNA ARRAY, LAVERTON W.A.
PIC BY CPL DAVE BROOS, DEFENCE PUBLIC AFFAIRS.



Antenna array at Alice Springs. This site had guyed antenna structures rather than free-standing structures as at Laverton above. *Image: source unknown.*

The equipment at each radar receiving station consists of:

- the receivers
- very powerful computers to process the returned signals
- operations and maintenance facilities
- backup diesel power stations
- staff amenities

It should be kept in mind that the sites are all in remote locations so need to be equipped for stand-alone operations.

The receivers have been an important part of the hardware development for OTHR projects. The receivers are complex and a large number are required for each receiving station. In recent developments the receivers are located near the individual antenna array elements and contain analogue to digital functionality so that the signal from the antenna to the equipment building can be transmitted in digital format.

Manufacturer's material on OTHR receivers can be found at Appendix 8.

A bank of 2-30 MHz receivers for OTHR use. These are manufactured by Rohde & Schwarz GmbH. The site of this image is not known. *Image: Rohde & Schwarz GmbH.*

Physical Condition: As the **JORN/Jindalee** facilities are operational they are maintained in good condition by the RAAF and Defence Science and Technological Group (DSTG) in the case of Alice Springs.

3.2 Historical Notes

A detailed history of the Jindalee/JORN project can be found in the paper by D H Sinnott, published by Defence Science and Technology Organisation (DSTO) 1988 [16].

The following 'potted history' is taken from the Wikipedia site titled Jindalee Operational Radar Network [17].

"The roots of the JORN can be traced back to post World War II experiments in the United States and a series of Australian experiments beginning in the early 1950s. From July 1970 a study was undertaken; this resulted in a proposal for a program to be carried out, in three phases, to develop an over-the-horizon-radar system.

Geebung

Phase 1, Project Geebung, aimed to define operational requirements for an over-the-horizon-radar (OTHR), and study applicable technologies and techniques. The project carried out a series of ionospheric soundings evaluating the suitability of the ionosphere for the operation of an OTHR.

Jindalee

Phase 2, Project **Jindalee**, aimed at proving the feasibility and costing of OTHR. This second phase was carried out by the Radar Division, (later, the High Frequency Radar Division), of the Defence Science and Technology Organisation (DSTO). Project Jindalee came into being during the period 1972-1974 and was divided into three stages.

Stage A commenced in April 1974. It involved the construction of a prototype radar receiver at Mount Everard, near Alice Springs, a transmitter at Harts Range, 160 km away and a beacon in Derby, WA. When completed (in October 1976) the Stage A radar ran for two years, closing in December 1978. Stage A formally ended in February 1979, having achieved its mission of proving the feasibility of OTHR. The success of stage A resulted in the construction of a larger stage B radar, drawing on the knowledge gained from stage A.

Stage B commenced on 6 July 1978. The new radar was constructed next to the stage A radar. Developments during stage B included real time signal processing, custom built processors, larger antenna arrays, and higher power transmitters, which resulted in a more sensitive and capable radar.

---

[16] Sinnott D H. The development of Over-the-horizon Radar in Australia. Defence Science and Technology Organisation (*DSTO),* Australian Department of Defence. Bicentennial History Series. 1988. ISBN 0 642 13561 4.
[17] Wikipedia. Jindalee Operational Radar Network. Last updated 1 April 2016. Viewed 19 April 2016. https://en.wikipedia.org/wiki/Jindalee_Operational_Radar_Network

- The first data was received by Stage B in the period April–May 1982
- the first ship was detected in January 1983
- an aircraft was automatically tracked in February 1984

Trials were carried out with the Royal Australian Air Force during April 1984, substantially fulfilling the mission of stage B, to demonstrate an OTHR operating in Australia. Another two years of trials were carried out before the Jindalee Project officially finished in December 1985.

Stage C became the conversion of the stage B radar to an operational radar. This stage saw substantial upgrades to the stage B equipment followed by the establishment of No.1 Radar Surveillance Unit RAAF (1RSU) and the handover of the radar to 1RSU. The aim was to provide the Australian Defence Force (ADF) with operational experience of OTHR [18].

JORN (Jindalee Operational Radar Network)

Phase 3 of the OTHR program was the design and construction of **JORN**. The decision to build the **JORN** was announced in October 1986. Telstra, in association with GEC-Marconi, became the prime contractor and a fixed price contract for the construction of the **JORN** was signed on 11 June 1991. The **JORN** was to be completed by 13 June 1997 [19].

Phase 3 Project Problems

Telstra was responsible for software development and systems integration, areas in which it had no previous experience. GEC-Marconi was responsible for the HF Radar and related software aspects of the project, areas in which it had no previous experience [20]. Other unsuccessful tenderers for the project included experienced Australian software development and systems integration company, BHP IT, and experienced Australian defence contractor AWA Defence Industries (AWADI). Both of these companies are no longer in business [21].

By 1996, the project was experiencing technical difficulties and cost overruns [22] [23]. Telstra reported an A$609 million loss and announced that it could not guarantee a delivery date [24].

---

[18] Colegrove Samuel B (Bren). Project Jindalee: From Bare Bones to Operational OTHR. IEEE International Radar Conference - Proceedings. IEEE. 2000. pp 825–830. Retrieved 17 November 2006.

[19] Ibid.

[20] "Jindalee Over-the-Horizon Project (JORN) : Extract from a Channel 9 television program broadcast on 23rd March 1997". www.ourcivilisation.com. *23 March 1997*. Retrieved 20 March 2014.

[21] Natasha David. "BHP IT purchase propels CSC to No. 2". Computerworld. 5 June 2000. Retrieved 20 March 2013.

[22] Colegrove Samuel B (Bren). "Project Jindalee: From Bare Bones To Operational OTHR" (PDF). IEEE International Radar Conference - Proceedings. IEEE. pp. 825–830. 2000. Retrieved 17 November 2006.

[23] McNally, Ray. "Jindalee Operational Radar Network: Department of Defence" (PDF). The Auditor-General Performance Audit Audit Report No.28 1995-96. Australian National Audit Office. 18 August 1996.Archived from the original (PDF) on 17 September 2006. Retrieved 17-11-2006.

[24] Sinclair-Jones Michael. "JORN assures early warning for Australia". Defence Systems Daily. Defence Data Ltd. 29 February 2000. Archived from the original on 16-11-2007. Retrieved 15-11-2006.

The failed Telstra contract prompted the project to enter a fourth phase.

Phase 4 involved the completion of **JORN** and its subsequent maintenance using a new contractor. In February 1997 Lockheed Martin and Tenix received a contract to deliver and manage **JORN**. Subsequently during June 1997 Lockheed and Tenix formed the company RLM Group to handle the joint venture. An operational radar system was delivered in April 2003, with maintenance contracted to continue until February 2007 [25].

Phase 5

As a consequence of the duration of its construction, **JORN** delivered in 2003 was designed to a specification developed in the early 1990s. During this period the Alice Springs radar had evolved significantly under the guidance of the DSTO. In February 2004 a fifth phase of **JORN** project was approved.

Phase 5 aimed to upgrade the Laverton and Longreach radars to reflect over a decade of OTHR research and development. It was scheduled to run until approximately 2011 [26], but was completed around 2013/2014 due to skills shortage. All three stations are now similar, and use updated electronics [27].

Phase 6

Future upgrade requirements for **JORN** are being considered as part of Joint Project 2025 Phase 6 and will not be decided until 2016/2017 [28].

Project Cost

The **JORN** project (JP2025) has had 5 phases, at a cost of approximately A$1.8 billion. The ANAO [29] Audit report of June 1996 estimated an overall project cost for Phase 3 of $1.1 billion [30]. Phase 5 costs have been estimated at $70 million" [31].

3.3 Heritage Listings

None known.

[25] Thurston Robin. "Projects: JP 2025 - Jindalee Operational Radar Network (JORN)". Defence Materiel Organisation Website. Department of Defence. 21 June 2006. Retrieved 15-11-2006.
[26] Ibid.
[27] Perrett Bradley. "Australia's Jindalee Radar System Gets Performance Boost". Aviation Week & Space Technology. 22 September 2014. Accessed 24 September 2014. Archived on 24 September 2014.
[28] Refer Appendix 5.
[29] ANAO = Australian National Audit Office.
[30] "Department of Defence : Jindalee Operational Radar Network : Performance Audit". Audit Report No. 28 1995-96 : Summary. Australian National Audit Office (ANAO). 18 June 1996. Retrieved 19 March 2014.
[31] Saun Gary. "JP 2025 - Jindalee Operational Radar Network (JORN)". Projects. Defence Materiel Organisation. Australian Department of Defence. 15 July 2009. Retrieved 19 March 2014.

4 Assessment of Significance

4.1 Historical significance:

Refer section 3.2.

4.2 Historic Individuals or Association:

In the case of Jindalee we are fortunate that much of the details of the story are not that long ago that the story has been largely forgotten. In looking for the names of those involved in the project I came to the conclusion that the paper by Don Sinnott, The Development of Over-the-horizon Radar in Australia [32] was the most comprehensive source of project participants available and hence this has been used as a source for the analysis below.

Participants are listed in the table below in the order that they are mentioned. This means that they are generally in chronological order as the paper is a story of OTHR in Australia starting from early work in Australia. Each name is only mentioned once in this table i.e. the first occasion when that name is mentioned in the paper. The table included a brief description of the role played by each individual including title if relevant and if stated. The year is either stated in the text or estimated if not specifically stated.

Appendix 3 contains biographical data for those key people for whom such material could be found. The individuals included in Appendix 3 are highlighted in yellow in the table below.

Entries in blue text are retirements of key staff involved in the project.

Name	Title and or description of Role	Year
George Carter	Department of Supply and Development, Electronics Research Division (ERD), Long Range Weapons Base Establishment, Salisbury, SA	1950s
Stan Lott	Defence Standards Laboratory, Maribyrnong, Melbourne	1950s
John Farrands	Defence Standards Laboratory, Maribyrnong, Melbourne. John Farrands was later Chief Defence Scientist	1950s
John Clegg	Department of Supply and Development, Electronics Research Division (ERD), Long Range Weapons Base Establishment, Salisbury, SA	1952

[32] Sinnott D H. The Development of Over-the-horizon Radar in Australia. DSTO Bicentennial Series. ISBN 0 642 13561 4. 1988. pages 6-42.

John Strath	Department of Supply and Development, Electronics Research Division (ERD), Long Range Weapons Base Establishment, Salisbury, SA	1953
Don Woods	Deputy Director, Weapons Research & Development	1958
W A S Butement [33]	Department of Supply Chief Scientist	1958
Graham Bird	Professor of Aeronautical Engineering, University of Sydney	1958
Bob Edgar	Department of Supply and Development, Electronics Research Division (ERD), Long Range Weapons Base Establishment, Salisbury, SA	1958
Arthur Wills	Chief Defence Scientist	C1968
Des Lamb	Part of team to visit the US to meet with US OTHR workers (also included John Strath and Bob Edgar)	Oct 1969
Ralph Cartwright	Part of team to visit the US to meet with US OTHR workers (also included John Strath and Bob Edgar)	Oct 1969
Malcolm Golley	Part of GEEBUNG Team led by John Strath, Senior Principal Research Scientist, Electronics Division, Applied Physics Wing, GEEBUNG Project Team. Bob Edgar was also in this team	1970
Fred Earl	Part of GEEBUNG Team led by John Strath, Senior Principal Research Scientist, Electronics Division, Applied Physics Wing, GEEBUNG Project Team. Bob Edgar was also in this team	1971
Bill Mettyear	Part of GEEBUNG Team led by John Strath, Senior Principal Research Scientist, Electronics Division, Applied Physics Wing, GEEBUNG Project Team. Bob Edgar was also in this team [34]	c1971
Bob Greig	Part of GEEBUNG Team led by John Strath, Senior Principal Research Scientist, Electronics Division, Applied Physics Wing, GEEBUNG Project Team. Bob Edgar was also in this team	c1971
Bob Dippy	Superintendent Electronics Division, John Strath's boss during Project GEEBUNG	c1971

[33] Wikipedia. W A S Butement. Last updated 1 April 2016.

[34] Bill Mettyear and Bob Greig along with John Strath as Team Leader became the management Team for Project GEEBUNG.

Alan Sharpe	Controller Research and Development, Department of Supply. (A minute written by Sharpe to the Director, Weapons Research Establishment on this date sealed the name JINDALEE for the Australian OTHR Project)	19 July 1972
Reg Phipps	JINDALEE, Stage A, Project Committee consisted of John Strath, Bob Greig and Bill Mettyear (Project triumvirate) plus Malcolm Golley, Fred Earl, Reg Phipps, Don Sinnott, Alan Tucker, Bill Rundle and Neil Bryans plus Dick Trenam and John Ellershaw from the Electronics Division all around the table	1972
Don Sinnott	Jindalee, Stage A, Project Committee (see entry above)	1972
Alan Tickner	Jindalee Project Committee	1972
Bill Rundle	Jindalee Project Committee	1972
Neil Bryans	Jindalee Project Committee	1972
Dick Trenam	Jindalee Project Committee	1972
John Ellershaw	Jindalee Project Committee	1972
Lance Barnard	Minister of Defence (He made a Press Release in April 1974 announcing approval of Project JINDALEE as the Australian OTHR)	July 1974
John Farrands	Chief Defence Scientist	Mid 1970s
Peter Drewer	Along with Neil Bryans they took charge of the waveform generator development program which was based on the Barra Sonar Program	Mid 1970s
Frank Cleggett	Defence Science and Technology Organisation (DSTO), Alice Springs Site Team, Project JINDALEE commenced	1974/75
Tom Suttie	Defence Science and Technology Organisation (DSTO), Alice Springs Site Team, Project JINDALEE commenced	1974/75
Roy Woods	Defence Science and Technology Organisation (DSTO), Alice Springs Site Team, Project JINDALEE commenced	1974/75
Jack Commander	Defence Science and Technology Organisation (DSTO), Alice Springs Site Team, Project JINDALEE commenced	1974/75

David Warren-Smith	Defence Science and Technology Organisation (DSTO), Alice Springs Site Team, Project JINDALEE commenced	1974/75
Peter Hattam	Defence Science and Technology Organisation (DSTO), Alice Springs Site Team, Project JINDALEE, Stage A, commenced	1974/75
Sir Arthur Tange	Secretary of Defence	c1975
Cyril Carter	Associate Professor of Electrical Engineering, Monash University, Melbourne	c1975
Bob Jarrott,	JINDALEE Stage B, DSTO, Project Team was led by John Strath, Bob Greig, Bill Mettyear and Don Sinnott (as for JINDALEE Stage A) plus most others who had participated in Stage A. The following were also added to the team: Bob Jarrott, Bren Colegrove, Steve Tucker, Stuart Anderson, Cyril Carter.	1975
Bren Colegrove	Jindalee, Stage B, Project Committee (see entry above)	1975
Steve Tucker	Jindalee, Stage B, Project Committee	1975
Stuart Anderson	Jindalee, Stage B, Project Committee	1975
Air Vice Marshal David Evans	Chief of Air Force Operations. Requested a paper on what would happen after JINDALEE Stage B. A paper titled "Life beyond JINDALEE Stage B" was produced to answer this question.	September 1979
Jim MacMillan	Subcontractor to Hills, the manufacturers of the Receiver antenna array at Mount Everard who, with the help of his wife erected the 980 antennas in the array in 32 days, an average of 30 per day.	1980
Warwick Kemp	Work Team who built the Darwin Beacon at HMAS *Coonawarra.* This beacon became central to calibration and frequency management during JINDALEE Stage B.	1980/1981
Angus Mussie	Work Team for Darwin Beacon (see entry above)	1980/1981
John Lane	Work Team for Darwin Beacon	1980/1981
John Strath	Retired the day before his 65th birthday as required by then Commonwealth employment rules	September 1981

Lester Soden	Superintendent of Radar Division (took over from John Strath on his retirement)	1981
Henry d'Assumpcao	Chief Superintendent of Electronics Research Laboratory Lester Soden's boss)	1981
Squadron Leader Peter Bevan	In a plan to prepare JINDALEE for operations four RAAF officers were to be posted to Radar Division at Salisbury. Peter Bevan was the most senior of what turned out to be only three officers.	1982
Flight Lieutenant Peter Gamgee	RAAAF officer posted to Radar Division (see entry above)	1982
Flight Lieutenant Steve Sheedy	RAAAF officer posted to Radar Division	1982
Bob Greig	Retired (the second of the Strath-Greig-Mettyear triumvirate to leave the scene).	July 1983
Peter Oswald	Station Director, Alice Springs, from Radar Division. This was the transition point for the station being operated by a contractor, Amalgamated Wireless of Australia (AWA).	c1983
Theo Nysen	AWA Senior Engineers based at Alice Springs OTHR. There was a total AWA staff of about 20.	c1983
Jim Wilcox	AWA Senior Engineers based at Alice springs OTHR. There was a total AWA staff of about 20.	c1983
Bill Mettyear	Retired (the last of the Strath-Greig-Mettyear triumvirate to leave the scene).	1985
Squadron Leader Peter Bevan	Completed his posting to Radar Division	1985
Terry Deecke (rank uncertain)	Replaced Peter Bevan in posting to Radar Division (see above entry)	1985
Lester Soden	Retired as Superintendent of the Radar Division.	May 1985
Harry Green	Appointed Superintendent of the Radar Division to replace Lester Soden (see entry above)	1985
Gordon Brimble	Software for JINDALEE Stage A and B.	1972-1985
Bob Blesing	Participated throughout JINDALEE Stage A and B	1972-1985
Alan Forbes	Participated throughout JINDALEE Stage A and B	1972-1985
Bruce Ward	Major force in the frequency management area, JINDALEE Stage A and B	1972-1985

Peter Roberts	Good work in the acquisition of major equipment for JINDALEE Stage A and B	1972-1985
Morrie Stevens	Software and integration for JINDALEE Stage A and B	1972-1985
Doug Priest	Drawing office for JINDALEE Stage A and B	1972-1985
Leigh McKenzie	Drawing office for JINDALEE Stage A and B	1972-1985
Gavin Perry	Custom computing equipment and software, JINDALEE Stage A and B	1972-1985
June Smith	Secretary and Personal Assistant to successive Superintendents of Electronics and Radar Divisions, beginning with John Strath in 1976	1976-1985
Kim Beazley AM [35]	Minister of Defence, press release, making the first public statement about the government intention to develop a network of OTHRs which eventually emerged as JORN	October 1986
Ken Perry	Marconi Radar Systems (MRS), contractor team Alice Springs OTHR	c1991

4.3 Creative or Technical Achievement:

The concept of a radar system looking beyond the horizon by bouncing radar signals off the Ionosphere had been around for some time since the early applications of workable radar appeared during the Second World War.

In the United States of America there were several large projects aimed at developing the concept but none achieved an operational radar system. Projects MADRE and COBRA MIST are described in Appendix 6.

It was Australian scientists and engineers, primarily from the Defence Science and Technology Organisation (DSTO) who persisted and achieved the breakthrough represented by the Jindalee Project. Perhaps this breakthrough would never have been possible before the advent of larger digital computers and the technology which saw solid-state radar receivers become a reality.

Despite the commissioning of **JORN** in 2003 the technology is far from mature. Scientists are now looking for improvements of greater range, an order of magnitude increase in resolution and other developments.

[35] Admitted as Member of the Order of Australia (AM), 11 June 1979 for “public service to Defence Science”.

Apart from Australia, only the United States and Russia (still glaring at one another across the Arctic), France, Iran and China have OTHR radar in operation at present. The challenge for Australian scientists now is to remain in the vanguard, and retain their reputation as the premier OTHR scientists on the planet.

For a country like Australia, with its huge land and sea areas to patrol, but supported by a relatively small economy the technical achievements of **Jindalee** are even more breathtaking.

The **JORN** radar system is regarded at the most capable radar in the world [36].

4.4 Research Potential:

The **Jindalee** story is well documented however the high security status of **JORN** makes some data difficult, if not impossible, to obtain. Only time will rectify this limitation.

A related issue is the need to bring the public knowledge of **Jindalee** more into the public domain. All Australians should be proud to live under the watchful eye of **Jindalee**, a truly amazing Australian invention which should be as well-known as Vegemite, Australia II and the Sunshine harvester. Achieving this remains a challenge for Engineers Australia and Engineering Heritage Australia.

4.5 Social:

Although much of the Australian public have very limited knowledge or even awareness of the existence of the **Jindalee/JORN** projects those who follow defence matters are well aware of the huge contribution which **Jindalee/JORN** makes to Australia.

Whilst much of this contribution is of a military character there are numerous non-military uses for Jindalee data such as search and rescue, border control, fisheries patrol, customs patrol and meteorological information.

The reality is that it is very difficult to hide from the distant but precise gaze of **Jindalee**.

4.6 Rarity:

Few countries have attempted to build and operate an Over-the-horizon radar network and none has achieved such a comprehensive and competent coverage as Australia has achieved, covering all our northern approaches out to a range of 3000 - 4000 km.

JORN/Jindalee is unique and the existing system should be retained for posterity when its present operational use is over.

It may be Australia's most significant technological feat, is unique in Australia and rare in global sense.

[36] MinMiester. Aviation forums, Modern Military Aviation, JORN.Key Publishing Ltd.9 February 2001.

4.7 Representativeness:

Setting aside the undoubted achievements of MADRE and COBRA MIST which did not achieve operational status, **Jindalee** now stands as the Gold Standard for OTHR internationally. There will always be a bit of **Jindalee** in every subsequent OTHR system, no matter where it is built and no matter what technical performance it achieves.

Hence **Jindalee** holds the undoubted prime position in terms of representativeness – the system on which all other successful operational OTHR's are based.

4.8 Integrity/Intactness:

Whilst parts of the original Stage A and Stage B have been removed to make way for the later stages at the Alice Springs site the rest of the **JORN** system remains in operation and is maintained for operational purposes. Integrity and Intactness are therefore at a very high level.

4.9 Statement of Significance:

What is significant?

The three operational **JORN** (Jindalee Operational Radar Network) stations, each consisting of a transmitting station and a receiving station, nominally located at Alice Springs, Northern Territory; Laverton, Western Australia and Longreach, Queensland together with other associated equipment scattered around the country and the Control Centre at Edinburgh Air Force Base in South Australia together constitute the **JORN** system.

This network of stations has the capability to observe air and marine targets from a range of about 1000 km out to a range of 3-4000 km in an arc across Australia's Northern Approaches. The capabilities of the system have continued to develop since the project commenced in the early 1970s.

How is it significant?

The **Jindalee** OTHR system is significant is several criteria.

The system demonstrates a high degree of technical achievement during the post-World War II period. The conceptual development, design and development of key components for the system and the writing of the complex software for the system was largely carried out in Australia primarily by officers of the Defence Science and Technology Organisation with specialist assistance from contractors.

This work placed Australia in the position of lead country for the development of OTHR technology, a position which has been maintained to the present time as the technology continues to develop.

The **Jindalee/JORN** network is also significant as the most important early example of a fully operational OTHR system. Although built much later than systems such as MADRE and COBRA MIST the **JORN** system was the first to play a key operational role in the securing of any nation's borders.

The **Jindalee/JORN** network is also significant as it demonstrates all the features of an operational system. Because it is still in operation it is currently an entirely complete system and this characteristic should be preserved when the network is finally shut down in the distant future.

The **Jindalee/JORN** network is significant in social terms to the Australian population as it forms a key part of the robust system of defences in place under the leadership of the Australian Defence Force. Australians might not know a lot about the nuts and bolts of **Jindalee** but they are acutely aware of the importance of a robust surveillance system as a part of our national defence strategy.

Why is it significant?

The **Jindalee/JORN** network is all important as it is an example of a system which is complete in every way because at present it is in operation.

It is a rare example of an OTHR system on a global basis.

The system is an example of a national system with far reaching surveillance capacity far beyond the capability of earlier radar systems. It enabled Australia to develop a more secure and more sophisticated approach to the protection of the nation. It can assist in the understanding of the development of long distance strategic radar systems.

4.10 Area of Significance:

Local Level

Jindalee clearly has local significance, particularly in the small communities which host the radar stations. Alice Springs is, perhaps, the best example.

Communities like 'The Alice' have been fighting the tyranny of distance for a long time. It all started with the Overland Telegraph which smashed message delivery time between England and Australia from months to hours. That was followed by many other events which chipped away at the tyranny of distance. The Inland Mission; the Flying Doctor, the School of the Air, the Stuart Highway, the North-South Transcontinental Railway – they all made a contribution. Then there was Pine Gap, looking into near-space and **Jindalee** looking over-the-northern-horizon to our Northern Approaches.

The people of Alice Springs are mightily proud of their endless fight against the tyranny of distance. This nomination should recognise their contribution, and the contribution of all the other communities and people living in the Outback and their never-ending fight against the tyranny of distance.

National Level

Jindalee was conceived as a national project and now it serves a national purpose.

The stations of the **JORN** network are spread across four jurisdictions and clearly operate as a national network. The ownership of **JORN** by both the RAAF and DSTG clearly indicate national significance for this project.

International Level

Australia leads the world in OTHR development and deployment.

The concept has been “shared” with the United States and “exported” to the few other countries who have seen a pressing need to follow in Australia’s and the United States’ footsteps and build OTHR systems.

5 Interpretation Plan

5.1 General Approach

This site is recommended as a **Virtual Interpretation** site for the following reasons:

- All components of the JORN network are high security military sites not open to the public. Visitors would require high level approval which would only be granted on a need-to-know basis.

- Little of the radar equipment can be seen from outside the property perimeter fences.

A ceremony is not therefore planned for any of these sites and there will be no interpretation panels located on the sites.

A web-based “story board” would however be designed for placing within the Engineering Heritage Register on the web page. This module would have similar characteristics to an interpretation panel i.e. a “virtual interpretation panel”.

5.2 The Virtual Web-based Interpretation Panel:

1. A title **“Jindalee Over-the-horizon Radar”.**
2. Logos of Engineers Australia, DSTG, RAAF, Commonwealth Government (generic) to be incorporated.
3. A small scale representation of the EHA marker plate.
4. The date and other details of the recognition process.
5. Highly legible text.
6. Map of the location of the major facilities (refer to map at page 11).
7. Brief captions for each photograph including attribution.
8. Total text should not exceed 1000 words.
9. Sized to be compatible with electronic devices.

5.3 Possible Interpretation themes for Virtual Interpretation Panel

The following themes have been assessed as possible themes for the interpretation panel:

1. What are **Jindalee** and **JORN**?
2. The history of the **Jindalee** and **JORN** projects
3. How does OTHR work?
4. What can **JORN** do to defend Australia?
5. People associated with the **JINDALEE** project

5.4 Preliminary Text Blocks for Web Interpretation

What are Jindalee and JORN?

Jindalee is the project name given to the research project to develop an over-the-horizon radar system for Australia. The work was carried our primarily by the **Defence Science and Technology Organisation (DSTO)** (and its predecessors) now known as **Defence Science and Technology Group** headquartered at Salisbury in South Australia.

Jindalee is an Aboriginal word for a place that the eye cannot see, or somewhere beyond where the eye can see.

JORN stands for **Jindalee Operational Radar Network.** It is an over-the-horizon radar network that can monitor air and sea movements over a vast area to the North and West of Australia. It has a range between 1000 km and perhaps 4000 km from the three radar stations which are located near Laverton, Western Australia, Alice Springs in the Northern Territory and Longreach in Queensland.

JORN is operated by the **Royal Australian Air Force (RAAF)** and has been operational since 2003. The total cost up to the time it was commissioned, including the research and development has been about $1800 million.

JORN is one of the most powerful tools used for the defence of Australia and the technology is world-leading.

194 words

The History of Jindalee

Australian scientists started working on the difficult technology of over-the-horizon radar in the 1950s.

In 1970 Project **GEEBUNG** defined the way forward for over-the-horizon radar for Australia.

With **GEEBUNG** completed work started on Project **JINDALEE Stage A** in 1972 and the **JINDALEE Stage A** radar was turned on at the Alice Springs station in 1976 and detected its first aircraft within weeks.

JINDALEE Stage B followed almost immediately and the much more capable **JINDALEE Stage B** radar was turned on at the Alice Springs station in 1982 and again detected aircraft very quickly.

The decision to build **JORN** was made in 1986 by the then Defence Minister Kim Beazley and the system was completed and commissioned in 2003.

JORN includes a Control Centre to coordinate the activity of the three stations. This is located at Edinburgh Air Force Base in South Australia.

Development work continued throughout the building of **JORN** and several stages of upgrades in capability have already been completed with others to follow as the technology matures and software and hardware developments are incorporated into the operational stations.

184 words

How does Over-the-horizon (OTH) Radar work?

The **JINDALEE** radar operates in the HF (High Frequency) range (5 to 30 MHz) [MHz stands for Mega Hertz which means a frequency of 5 to 30 million cycles per second].

In comparison conventional line-of-sight radars (such as air traffic control radars) operate in the much higher frequency band called Microwave between 300 MHz to 300,000 MHz.

The secret of over-the-horizon radar is that the radar signal from the transmitter station is bounced off the underside of the i**onosphere** about 70 to 1000 km above the surface of the Earth to the target and is then returned by the same method to the receiver station. The i**onosphere** is a layer of the Earth's atmosphere which is ionized by solar and cosmic radiation.

The receiver and transmitter stations in the **JINDALEE** system are located about 100 km apart to avoid interference between the outgoing and incoming radar signals.

The returning signals are converted from analogue form to digital form at the receiver station so that they can be manipulated and conditioned to reveal the target image. Very powerful computing facilities are required to do this task and this has been a major focus of the Australian research.

Functional Over-the-horizon radar was very difficult to achieve until powerful digital computers became available.

216 words

What can JORN do to defend Australia?

JORN can detect aircraft and ships far off the Northern and Western coasts of Australia. Aircraft and ship types can be identified by the radar including stealth military aircraft. Quite small targets down to the size of metal fishing boats can be detected.

The capability of the radar system is being constantly upgraded to increase its capability so that it can 'see' more targets with greater detail and at greater range.

This tool is of immense importance for the **Australian Defence Force** to protect the approaches to Australia. The radar can also be used for civilian purposes such as fishery patrol, customs patrol and search and rescue functions.

115 words

People associated with the JINDALEE Project

A very large team of scientists and engineers has worked on the project for decades. Although **Defence Science and Technology Organisation (DSTO)** took the lead in the research there were many other organisations involved including the **Royal Australian Air Force (RAAF)** who operate **JORN**.

Many contractors with particular areas of expertise were utilised both in Australia and overseas. These contractors were involved in supply of equipment, development of software, construction of the stations and operational maintenance of the stations.

In addition to the Australian resources used in the research program Australia was assisted by the United States in particular as they had a particular interest in over-the-horizon radar for missile detection, particularly during the Cold War.

One person who worked for DSTO and who led the **GEEBUNG** and **JINDALEE** projects was **John Alexander Wiseman Strath**. He worked on Over-the-horizon Radar from 1953 until he retired in 1881. He guided **JINDALEE** from an almost-impossible dream to reality, dealing with the political problems and the physical ups and downs of the project.

He provided inspirational leadership and should be acknowledged by all Australians as having made a huge contribution to the nation.

John Strath died in 2009 leaving Australia a much safer place.

207 words

Total 916 words

6 List of References:

Listed in alphabetical order by author's family name:

Channel 9."Jindalee Over-the-Horizon Project (JORN) : Extract from a Channel 9 television program broadcast on 23rd March 1997". www.ourcivilisation.com. 23 March 1997. Retrieved 20 March 2014.

Chlanda Erwin. Nowhere to Hide When Alice's Radar Zeroes In. Alice Springs News. 28 April 2004.

Colegrove Samuel B (Bren). "Project Jindalee: From Bare Bones To Operational OTHR" (PDF). IEEE International Radar Conference - Proceedings. IEEE. pp. 825–830. 2000. Retrieved 17 November 2006.

"Department of Defence : Jindalee Operational Radar Network : Performance Audit". Audit Report No. 28 1995-96 : Summary. Australian National Audit Office (ANAO). 18 June 1996. Retrieved 19 March 2014.

Diario SWL 15-56578 Antonio. 29B6: Russian FMP OTH Radar KONTAINER. Downloaded 22 April 2016.

"Digisonde Station List". University of Massachusetts Lowell, Center for Atmospheric Research. February 2004. Retrieved 29 November 2006.

Federation of American Scientists (FAS).AN/FPS-118 Over-the-horizon Backscatter (OTH-B) Radar. http://www.fas.org/nuke/guide/usa/airdef/an-fps-118.htm

Frissall and Hockersmith.2008.page 3.

Gardiner-Garden R S. "Ionospheric variability in sounding data from JORN". Workshop on the Applications of over the horizon radar.

Global Security. www.globalsecurity.org
http://www.globalsecurity.org/wmd/world/russia/steel-yard.htm

Golley Malcolm Dr. Strath, John Alexander Wiseman. Obituary. c2009.

Google Maps image of Receiver Site near Wenzou, south of Shanghai in China receiver.

Google Maps image of Transmitter Site near Wenzou, south of Shanghai in China transmitter.

Honeysuckle Creek and Island Lagoon website.
http://honeysucklecreek.net/other_stations/island_lagoon/index.html

Kennedy Pete. Alice Springs News Online. c2008. downloaded July 2015.

Liu Bin-Yi. HF Over-the-horizon Radar System Performance Analysis. Naval Postgraduate School, Monterey, California, United States of America. September 2007. Thesis.

McNally, Ray. "Jindalee Operational Radar Network: Department of Defence" (PDF). The Auditor-General Performance Audit Audit Report No.28 1995-96. Australian National Audit Office (ANAO). 18 August 1996. Archived from the original (PDF) on 17 September 2006. Retrieved 17 November 2006.

MinMiester. Aviation Forums, Modern Military Aviation, JORN. Key Publishing Ltd. 9 February 2001.

Natasha David. "BHP IT purchase propels CSC to No. 2". Computerworld. 5 June 2000. Retrieved 20 March 2013.

Pike John. Steel Yard OTHR. Retrieved 8 April 2010. Last update 1 December 2015. www.global.security.org

Perrett Bradley. "Australia's Jindalee Radar System Gets Performance Boost". Aviation Week & Space Technology. 22 September 2014. Archived on 24 September 2014. Accessed 24 September 2014.

Polemer Mediterranee. Stradivarius. http://en.polemermediterranee.com/DAS-Projets/Maritime-Safety-and-Security/Surveillance-and-maritime-intervention/STRADIVARIUS

Radio Science (WARS), Leura, NSW. February 2006. Retrieved 29-11-2006.

Saun Gary. "JP 2025 - Jindalee Operational Radar Network (JORN)". Projects. Defence Materiel Organisation. Australian Department of Defence. 15 July 2009. Retrieved 19 March 2014.

Siminski Jacek. The Aviationist. 12 December 2013.

Sinclair-Jones Michael. "JORN assures early warning for Australia". Defence Systems Daily. Defence Data Ltd. 29 February 2000. Archived from the original on 16-11-2007. Retrieved 15-11-2006.

Sinnott D H. The development of Over-the-horizon Radar in Australia. Defence Science and Technology Organisation (DSTO), Australian Department of Defence. Bicentennial History Series. 1988. ISBN 0 642 13561 4.

The Adelaide Advertiser newspaper. Notices relating to the death of Bill Mettyear. 30 December 2015.

Thurston Robin. "Projects: JP 2025 - Jindalee Operational Radar Network (JORN)". Defence Materiel Organisation Website. Department of Defence. 21 June 2006. Retrieved 15-11-2006.

Walker Rosanne. Encyclopedia of Australian Science. Created 25 May 2001. Last modified 15 September 2011. http://www.eoas.info/biogs/P003976b.htm

Wikipedia. 29B6 Kontayner OTH Radar. Last updated 22 April 2016. Downloaded 2 May. 2016.

Wikipedia. W A S Butement. Last updated 1 April 2016. Downloaded 19 April 2016.

Wikipedia. Cobra Mist. Last updated 4 April 2016. Downloaded 19 April 2016. Page 1.

Wikipedia. Container Radar. Last updated 12 November 2015. Downloaded 22 April 2016.

Wikipedia. Duga-1 and Duga-2. Last Updated 2 Feb 2014. Downloaded 22 April 2016.

Wikipedia. Duga Radar. Last updated 16 April 2016. Downloaded 22 April 2016.

Wikipedia. Jindalee Operational Radar Network. Last updated 1 April 2016. Viewed 19 April 2016. https://en.wikipedia.org/wiki/Jindalee_Operational_Radar_Network

Wikipedia. Over-the-horizon Radar. Updated 3 April 2016. Downloaded 19 April 2016.

Wikipedia. Sepehr (radar). Last updated 5 July 2015. Downloaded 22 April 2016.

Wise John C. "Summary of recent Australian radar developments" (PDF). IEEE A&E Systems Magazine (IEEE) (4): 8–10. December 2004. Retrieved 29 November 2006.

7 Acknowledgments, Authorship and General Notes

7.1 Acknowledgments

I wish to acknowledge the paper written by Don Sinnott titled "The Development of Over-the-horizon Radar in Australia" (1988) as this formed a key element in unravelling the somewhat complex story which led to **JINDALEE** and **JORN**. The clarity of this 43 page paper is remarkable and allowed the sequence of events, dates and people involved in the project to be defined with ease.

I also wish to acknowledge the contribution made by Dr Bruce Ward, Chief Technology Officer, DSTO who made a presentation to Engineers Australia, Victoria Division on 3 December 2013 titled "From Bare Bones to Operational Capability – the Story of the Jindalee Project". I also thank Bruce for recommending the work by Don Sinnott as mentioned above.

My long-time friend and compatriot from the years with the Northern Territory's excellent Power and Water Authority, Trevor Horman, must also take great credit for encouraging me to pursue the story of **JINDALEE** even after I had left the Territory and moved to Melbourne.

Finally I want to thank and congratulate everybody (those who have now gone and those who remain) who worked so hard and so long to make **JINDALEE** a success. **JINDALEE** is up there with the nation's all-time highest technical achievements and we owe these people a great debt. Australian is now a safer country, thanks to **JINDALEE**.

7.2 Nomination Preparation

This nomination was prepared by:

Owen Peake
FRMIT HonFIEAust CPEng
[Fellowship Diploma of Electrical Engineering, 1964]
4 Islington Street
Collingwood Victoria 3066
Phone: +61 3 9419 0820 (home and work)
Email: owen.peake@bigpond.com

7.3 General Notes

This document has been prepared in accordance with the Commonwealth Government Style Manual for authors, editors and printers, Sixth Edition, revised by Snooks & Co, 2002.

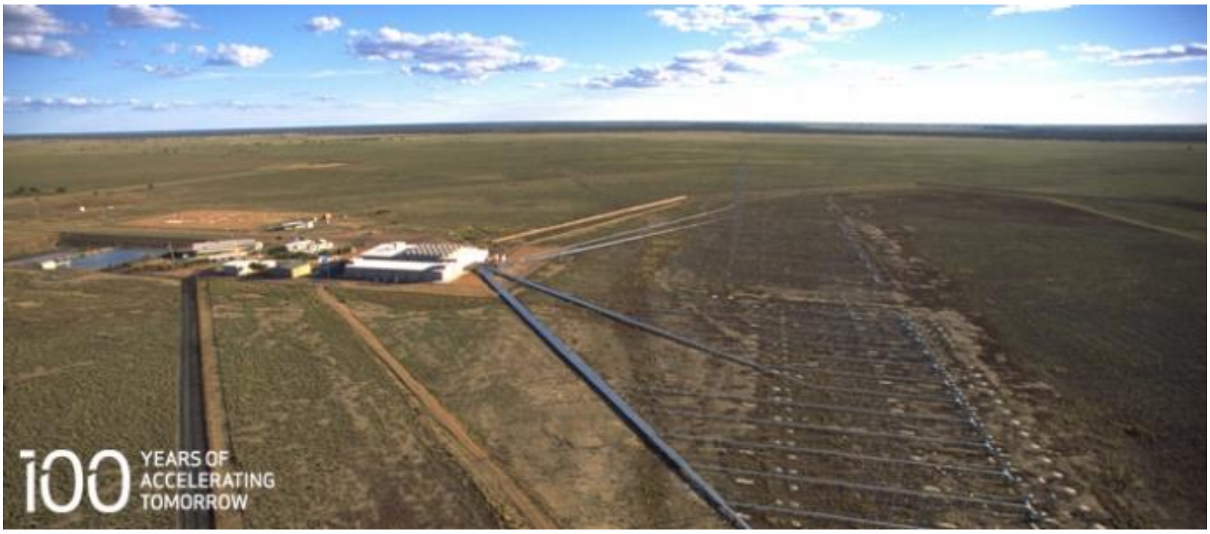
The method of citation used in this document is the Vancouver System. See page 190 of the above Style Manual.

Appendix 1: Images with Captions

The nature of the country near the Jindalee Base at Mount Everard near Alice Springs. This view is from the adjacent Yuendumu Road and illustrates that nothing of the base can be seen from the road. The Power and Water 22 kV power line feeds the base and other customers in the area. *Image: Owen Peake*

Receiver antenna array at Mount Everard with BAE systems (contractor) staff.
Image BAE Systems.

Antenna array at Mount Everard with RAAF FA-18 Hornets flying low overhead. RAAF Squadron No.75 Hornets operate out of Tindal Air Force Base near Katherine 25 minutes [37] flying time from the Alice Springs JINDALEE Receiver station.
Image: source unknown.



Longreach JORN Transmitter Site showing extensive site facilities (left) and antenna array (right). The access road is at the extreme left.
Image: Lockheed Martin

[37] Based on a distance of approximately 750 km. The Hornet has a top speed of Mach 1.8 (1915 km/h at 40000 feet). Obviously the pilot would have to be in a hurry and have plenty of fuel!

CAND98/0153-03
JORN PROJECT RECEIVER SITE, LAVERTON W.A.
PIC BY CPL DAVE BROOS, DEFENCE PUBLIC AFFAIRS.

CAND98/0153-04
JORN PROJECT TRANSMITTER SITE, LAVERTON, W.A.
PHOTO BY CPL DAVE BROOS, DEFENCE PUBLIC AFFAIRS

Longreach JORN Transmitter site. ***Image: Australian Aviation***

Laverton JORN Receiver Site facilities. ***Image: Defence Materials Organisation, Department of Defence.***

JORN operator station. ***Image: BAE Systems.***

Longreach Receiver Array. ***Image: Department of Defence.***

Appendix 2: Maps / Satellite Images

Laverton Transmitter Station, Western Australia. ***Image: Google Earth***

Laverton Receiver Station, Western Australia. ***Image: Google Earth.***

Harts Range Transmitting Station, Northern Territory. ***Image: Google Earth***

Mount Everard Receiving Station, Northern Territory. ***Image: Google Earth***

Longreach Transmitting Station, Queensland. *Image Google Earth*

Longreach Receiver Station, Queensland. *Image: Google Earth*

Appendix 3: Historic Individuals or Associations

3.1 John Strath

BIOGRAPHICAL ENTRY [38]

Strath, John Alexander Wiseman (1916 - 2009)

Born	21 September 1916
	Scotland
Died	26 February 2009
Occupation	Physicist

Summary

John Alexander W. Strath and his staff at Weapons Research Establishment made fundamental contributions to our understanding of the ionosphere, to antenna design, frequency management and computing systems. This made it possible to develop Jindalee, which could make observations of aircraft at great distances from our coast with great precision.

Details

Born Scotland, 21 September 1916. AM. Educated University of Edinburgh (MA Hons 1938, BSc Hons 1939). Principal Research Scientist, Weapons Research Establishment 1952-68, Senior Principal Research Scientist 1968-70, Superintending Scientist, Electronic Research Division 1973-81, Acting Deputy Director, Space Physics Wing 1975-78. Fellow, Australian Academy of Technological Sciences and Engineering 1979; CSIRO Medal for Research Achievement; Mann, Mackay Smith and Nichol Scholarships; Ramsay Memorial Medal; Norman Lucas Prize.

Published resources - Online Resources

- 'Strath, John Alexander Wiseman (1916-)', *Trove*, National Library of Australia, 2009,http://nla.gov.au/nla.party-1475881.
- Academy of Technological Sciences and Engineering, *Technology in Australia 1788-1988*, Online edition, Australian Science and Technology Heritage Centre, Melbourne, 3 May 2000, http://www.austehc.unimelb.edu.au/tia/index_s.html.
- Wisdom, John, *A History of Defence Science in Australia*, Defence Science and Technology Organisation, Melbourne, 1995, 267 pp.

Foundation Supporter - ARC Learned Academies' Special Projects

STRATH John Alexander Wiseman [39]

[38] Walker Rosanne. Encyclopedia of Australian Science. Created 25 May 2001. Last modified 15 **September 2011.** http://www.eoas.info/biogs/P003976b.htm

[39] Golley Malcolm Dr. Strath John Alexander Wiseman. Obituary. c2009.

21 September 1916 - 26 February 2009

John Strath AM FTSE, a renowned defence scientist and one of the 'fathers' of Australia's Jindalee radar system, died on 26 February aged 92 years.

Born and educated in Scotland, in 1939 he obtained an MA and BSc, with honours in Mathematics and Physics, from Edinburgh University.

After being mobilised in 1940 as a civilian scientific adviser to Orkney and Shetland Defences, in 1941 he joined the research staff of Telecommunications Research Establishment at Swanage and Great Malvern, England. Over the next seven years he was closely involved in the development of techniques and components for various blind bombing aids.

After the war he participated in a special mission to Norway and was subsequently responsible for the initiation of early work on centimetric upper air precision sounding techniques.
In 1952 John joined the Weapons Research Establishment, forerunner of today's Defence Science and Technology Organisation (DSTO), at Salisbury, South Australia. His early work included provision of support to the signal intelligence community and pioneer investigations at Woomera on the HF cross section enhancement of a ballistic missile during its passage through the upper atmosphere.

This work led him to speculate on the possibility of aircraft detection with over the horizon radar (OTHR), using radio reflections from the ionosphere – a layer enveloping the earth at a few hundred kilometres height.

During 1968 he was made aware of highly classified OTHR programs in the US. By 1972 he had helped establish a formal arrangement between the US and Australia on OTHR, ensuring support at home for a program that became Jindalee. This involved the building of two demonstrator OTHRs of increasing complexity in Central Australia to assess the value of the technology to defence surveillance.

Ironically, John was forced, by public service regulations, to retire on the eve of his 65th birthday, at a time of great progress and excitement. Nonetheless, he maintained a keen and critical interest in the project until he was in his 90s.
The success of the Jindalee program led to the Jindalee Operational Radar Network, a critical element in Australia's defence surveillance. DSTO counts it as its crowning achievement.

In 1979 John was made a Member of the Order of Australia for public service to defence science. In the same year he was elected a Fellow of this Academy.

– Dr Malcolm Golley FTSE

3.2 Bill Mettyear

Born 8 April 1929, England

Died 25 December 2015, Morphett Vale South Australia age 86

Bill Mettyear (sitting in foreground), Station Director, Island Lagoon Tracking Station (DSS-41), NASA/Department of Supply, Woomera, SA, 1963-1964. ***Image: Colin MacKellar's web site*** [40]

[40] Honey suckle Creek and Island Lagoon website. http://honeysucklecreek.net/other_stations/island_lagoon/index.html

METTYEAR, Bill [41]

METTYEAR, Bill. Passed away peacefully on December 25, 2015 Aged 86 years. Beloved husband of Olive "A wonderful man" Loving Dad of Margaret (deceased), Bill, George, David, and their partners. A cherished grandad by his grand-children and great-grandchildren.
Obituaries
Published in The Advertiser on 30/12/2015
- See more at:
http://tributes.adelaidenow.com.au/notice/237332041/view?random=1461418711259?random=1461418711467#sthash.htBGIFB8.dpuf

METTYEAR, Bill

METTYEAR, Bill. BILL's FAMILY and FRIENDS are invited to attend his Funeral Service to be held in the Simplicity Funerals Chapel, 747 South Road, Black Forest on WEDNESDAY, January 6, 2016, commencing at 2.00 p. m. A donation in memory of Bill to the South Australian Voluntary Euthanasia Society would be appreciated. Envelopes will be available at the Chapel. Black Forest 8297 9555
Funerals
Published in The Advertiser on 30/12/2015

Simplicity Funerals

- See more at:
http://tributes.adelaidenow.com.au/notice/240992048/view?random=1461418758250?random=1461418758475#sthash.pUnwwu9R.dpuf

[41] The Adelaide Advertiser newspaper. Notices relating to the death of Bill Mettyear. 30 December 2015.

3.3 Don Sinnott

About the Author [42]

Donald Hugh (Don) Sinnott is a graduate of Melbourne University (BE in Electrical Engineering, 1966; M Eng Sc, 1967) and Syracuse University, New York, USA (PhD, 1972). He has been active in research in areas of applied electromagnetics, including radio frequency devices and antennas.

His work in the antenna area led to his becoming involved at an early stage in the JINDALEE Project; John Strath sought his involvement in 1972 when the Development Cost Plan for the Project was being drafted and Don contributed to planning and estimating at this stage. As the Project proceeded Don contributed as a consultant on antenna matters, without becoming a member of the designated Project team, until 1974 when he was seconded full-time to the Trade Off Studies Team of the Project to assist in the planning and design of the JINDALEE Stage B configuration.

Promoted to Senior Research Scientist (1975) and Principal Research Scientist heading Radio Group (1979) he became responsible for the design and implementation of the JINDALEE receiving antenna array and beam forming systems, as well as advising on other antenna and radio systems matters.

In 1983 Don was promoted to the position of Senior Principal Research Scientist in Radar Division and became much more involved in policy and planning matters for both the JINDALEE Project and for Research in the field of radar in general. Following the retirement in 1985 of Lester Soden as Radar Division Superintendent and JINDALEE Project Manager Don acted in the position for over six months until the present incumbent, Harry Green, took up the position in February 1.986. Since October 1987 Don has been Chief of the newly-formed Microwave Radar Division.

---

[42] Sinnott Don. The Development of Over-the-horizon Radar in Australia. Extract. 1988. page 42.

3.4 Ken and Ann Perry

Jindalee radar pioneer Ken Perry dies [43]

Ken and Ann on their 50th wedding anniversary. ***Image: Alice Springs News Online.***

HORIZON

Perry

HF radars operate in two quite distinct modes to bend or reflect their beams over the horizon.

In the shorter range surface wave radars the beam bends to follow the curve of the earth. The longer range versions bounce their beams off the ionosphere many thousands of miles round the globe — called skywave.

Surfacewave — in which the antennas are located on a sea-shore or on a ship and their vertically-polarised transmissions travel to an over-the-horizon target (e.g. ship or low flying aircraft) by coupling into the conductive seawater (made so by the free chlorine ions from the salt).

We built several such radars, both sea-going, and land-based at about the time of the Falkland Islands conflict, having earlier completed detailed project definition of large coastal defence HF radars designed to detect bombers approaching the UK coast a few hundred feet above the sea.

Many readers will be familiar with these radars; we had the fascination of working in a technology which enables visibility of targets normally hidden beyond the horizon.

Excitement

The excitement of our first OTH detection, a Falcon bomber flying at 500ft over the North Sea remains still; the crew were astonished too that we could 'see' their aircraft. We soon extended our OTH expertise to Canberra aircraft and to ships.

We have been helped in our trials by Tornado aircraft which willingly became very low-flying OTH targets

Beam paths of skywave or ionospheric radar (General Electric photo)

What is HF radar?

Newspaper article describing how OTHR works. ***Image: Alice Springs News Online.***

[43] Kennedy Pete. Alice Springs News Online. c28 July 2015.

OBITUARY by PETE KENNEDY

Intruding aircraft can fly just a few feet above the sea, below the cover of microwave defence radars: In order to track this threat, with his expertise in microwave, Ken Perry oversaw the development and production of high frequency surface wave "over-the-horizon" (OTH) radar.

A huge antenna is spreading for a kilometer or so on the ground off the Yuendumu Road, north-west of Alice Springs, and a second similar facility is north of the Plenty River Road.

Ted Pegram, of Marconi Radar Systems (MRS), which set up the facility, said in the company's Silver Jubilee publication in 1994: "In addition to detecting ships and low flying aircraft, this class of radar can also monitor the state of the sea surface, including surface current speed and direction, and wave height.

"These abilities can be used to track oil spillage from tanker accidents."

In the last decade of his career Ken played a significant role in the award to GEC-Marconi of the major contact with the Australian Government for the design and implementation of the Alice Springs facility.

Ken, Ann and their four girls. *Image: Alice Springs News Online*

"This has proved to be one of the most successful radars of this class ever undertaken and will be in operation for years to come," with Ken and John Bodonyi receiving the Nelson Gold Medal 1994.

MRS's Gerry Valentine said: "Ken he was transferred from the Research Department to MRS 1983 to 'mastermind' the development High Frequency Surface Wave 'Over The Horizon ' Radar (HF SWOTH) aided by John Bodonyi, Ted Pegram and others.

"In 1988 when, Marconi Radar Systems was one of 169 firms who registered interest in the Jindalee Operational Radar Network (JORN), Ken came to Australia and was instrumental in securing the contract for collaboration with Telecom Australia.

"After a protracted study a major contract was signed in 1991 and a large group of engineers moved to Australia with John Pearce appointed Project Manager.

"Ken used his powers of persuasion to get company agreement to take it on as there had been severe misgivings within senior management at MRS."

Ken Perry was born in Harrogate, England on June 7, 1930, evacuated to Blaenau Ffestiniog in North Wales, went to Ffestiniog's grammar school then continued in Sunderland.

In 1948 he was called up for national service with the RAF at Lossiemouth. He studied physics with mathematics at Newcastle University, joining Marconi in the early 1950s.

There he became an expert on the design and manufacture of microwave components for high-powered radar systems.

In 1956 he met Ann McEntee and they were married at Brentwood Cathedral in 1958. They had four daughters – Karen, Alison, Rachel and Nina.

Ann remembers receiving a phone call from the late John W. Sunderland CBE, vice-chairman of the Marconi Company between 1982 and 83 when he retired, an MRS executive, in which he said that Ken had "saved the company".

Ann, Ken and one of their children. ***Image: Alice Springs News Online.***

All the evidence seems to confirm his pivotal role in the development and subsequent promotion of OTHR.

He continued to work with MRS for seven years after his 65th birthday being named as the inventor of “near-vertical incidence HF radar” on a patent application in 2001, signalling some small recognition for a lifetime’s work.

After departing Marconi in 2002 he returned to give lectures there for many years. He also did lectures at the Institute of Engineering and Technology annually and supported his wife’s homeopathic interests.

He retired to Goldhanger becoming tower captain and organ player at St Peter’s church. He translated many hymn tunes into a suitable form to play on the church’s eight bells. The legacy is a web page of scores, forty hymns and thirty carols now used in other churches.

Ken died on 28th July 2015.

Appendix 4: Timeline of Key Dates in the Jindalee Story

1949	Russian Duga-2 VEYER OTHR system reported but no evidence of its success is available [44].
Early 1950s	First work on OTHR concept in Department of Supply and Development, Electronics Research Division (ERD), Long Range Weapons Base Establishment, Salisbury, South Australia [45].
Late 1950s-1961	The United States Navy Research Laboratories built a prototype OTHR called MADRE on Chesapeake Bay. Aircraft were detected in 1961 [46].
1953	John Strath commenced work on OTHR in Department of Supply and Development, Electronics Research Division (ERD), Long Range Weapons Base Establishment, Salisbury, South Australia [47].
1964-1973	The United States built an OTHR system called COBRA MIST starting in 1964. The project was originally to be built in Turkey however Turkey withdrew support and the project was moved to Orford Ness in Suffolk, England. After severe interference problems prevented the radar from operating the project was abandoned in 1973 [48].
October 1969	A specialist mission headed by John Strath visits the United States to talk to OTHR scientists there. This was the beginning of a long-term joint relationship on OTHR between Australia and the United States [49].
1970	Project GEEBUNG commenced in Australia aimed at defining a future OTHR project for Australia [50].
1970	United States Air Force AN/FPS-118 OTHR system commissioned at Moscow Air Force Base, Maine, USA [51].
1972	Project JINDALEE Stage A commenced at Salisbury, South Australia [52].
1974	Minister for Defence Lance Barnard, announces by press release that he has approved the Australian OTHR Project JINDALEE [53].

[44] Refer Appendix 6.
[45] Refer section 3.2.
[46] Refer Appendix 6.
[47] Refer table at section 4.2.
[48] Refer Appendix 6.
[49] Refer table at section 4.2.

[50] Refer table at section 4.2.

[51] Refer Appendix 7.
[52] Refer table at section 4.2.

[53] Refer table at section 4.2.

1975	Project JINDALEE Stage B commenced at Salisbury, South Australia [54].
1976	Russian DUGA-3 STEEL YARD OTHR system at Gomel, Ukraine Commissioned [55].
October 1976	The JINDALEE Stage A radar was turned on. An aircraft was detected shortly after [56].
1981	John Strath retires from Defence Science and Technology Organisation (DSTO) [57].
April 1982	The final components for JINDALEE Stage B were delivered to Alice Springs and within one month the first aircraft had been detected [58].
1982	RAAF become involved in JINDALEE with officers posted to Salisbury to prepare the Alice Springs radar for operations [59].
1986	Minister for Defence, Kim Beazley, announces in a press release that the government intends to develop a network of OTHR radars. (This eventually emerged at JORN) [60].
1989/1990	The Berlin Wall comes down essentially ending the Cold War between the Western Allies and the USSR [61]. The interest in developing OTHR for the detection of nuclear missiles reduced greatly, slowing, in particular, United States interest in OTHR technology [62].
1991-1993	The United States Navy builds a Relocatable OTHR radar termed AN/TPS-71 and deploys it in several locations in the US [63].
1990s	France commissions its NOSTRADAMUS OTHR and by 1999 reports successful results [64].

[54] Refer table at section 4.2.

[55] Refer Appendix 7.

[56] Sinnott D H. The Development of Over-the-horizon Radar in Australia. DSTO Bicentennial Series. ISBN 0 642 13561 4. 1988. page 26.

[57] Sinnott D H. The Development of Over-the-horizon Radar in Australia. DSTO Bicentennial Series. ISBN 0 642 13561 4. 1988. page 34.

[58] Sinnott D H. The Development of Over-the-horizon Radar in Australia. DSTO Bicentennial Series. ISBN 0 642 13561 4. 1988. page 34.

[59] Sinnott D H. The Development of Over-the-horizon Radar in Australia. DSTO Bicentennial Series. ISBN 0 642 13561 4. 1988. page 37.

[60] Sinnott D H. The Development of Over-the-horizon Radar in Australia. DSTO Bicentennial Series. ISBN 0 642 13561 4. 1988. page 30.

[61] Wikipedia. Berlin Wall. Last updated 13 April 2016. Downloaded 25 April 2016.

[62] Peake Owen. Opinion. April 2016.

[63] Refer Appendix 7.

[64] Refer Appendix 7.

2 April 2003 The Australian three-station OTHR termed JORN is commissioned [65] [66] [67].

c2013 The Russian KONTAINER OTHR system is reported to be commissioned [68].

2015 France commissions its STRADIVARIUS OTHR system [69].

---

[65] Refer Section 3.2.
[66] Refer Appendix 5.
[67] Liu Bin-Yi. HF Over-the-horizon Radar System Performance Analysis. Naval Postgraduate School, Monterey, California, United States of America. September 2007. Thesis.

[68] Refer Appendix 7.
[69] Refer Appendix 7.

Appendix 5: RAAF Fact Sheet – Jindalee Operational Radar Network

FACT SHEET

Jindalee Operational Radar Network

Australia's Jindalee Operational Radar Network (JORN) comprises three Over-The-Horizon Radar (OTHR) systems and forms part of a layered surveillance network providing coverage of Australia's northern approaches

What is an Over-the-Horizon Radar?

- An OTHR is a type of radar designed and operated specifically to see 'over the horizon'. Conventional microwave radars such as those commonly seen at airports propagate in a straight line and cannot detect objects beyond their line of sight i.e. beyond the visual horizon. OTHRs overcome this limitation by 'bouncing' High Frequency (HF) radio waves off the ionosphere.

- OTHR utilises the refractive properties of the ionosphere to refract or bend transmitted HF electromagnetic waves back to Earth. When these refracted HF waves hit a radar reflective (metal) surface of sufficient size — either airborne or maritime — some of the energy is reflected back along the transmission path to the OTHR receiver. Sophisticated computer systems then process the received energy to discern objects within the radar's footprint.

AIR FORCE

How does it work?

- OTHR systems operate on the Doppler principle, where an object can be detected if its motion toward or away from the radar is different from the movement of its surroundings.

- OTHRs are typically made up of very large fixed transmitter and receiver antennas (called 'arrays'). The location and orientation of these arrays determines the lateral limits or arc of a radar's coverage. The extent of OTHR coverage in range within this arc is variable and principally dependent on the state of the ionosphere.

- OTHRs do not continually 'sweep' an area like conventional radars but rather 'dwell' by focusing the radar's energy on a particular area — referred to as a 'tile' — within the total area of coverage. The transmitted HF energy can be electronically steered to illuminate other 'tiles' within the OTHR's coverage as required to satisfy operational tasking or in response to intelligence cuing.

- OTHR key operating principles are depicted in Figure 1.

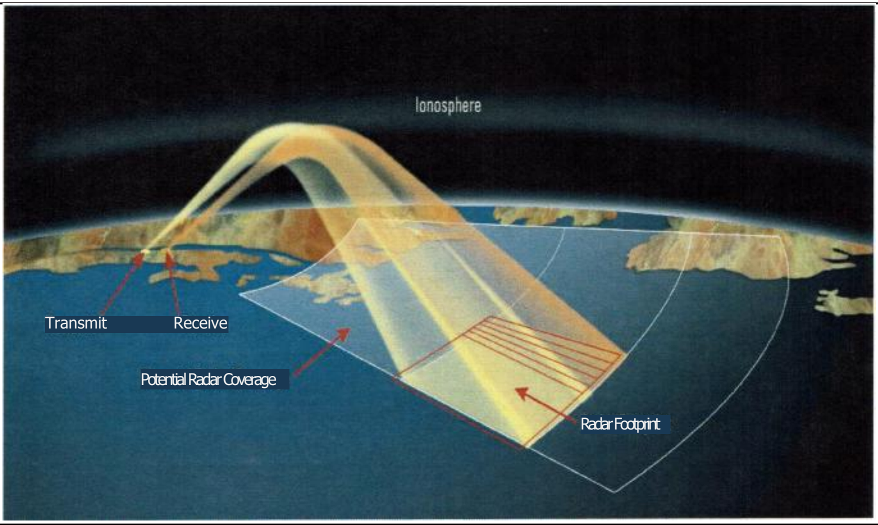


Figure 1: Key OTHR Operating Principles

What is JORN?

- The Australian Defence Force (ADF) currently operates three OTHR systems as part of the Jindalee Operational Radar Network (JORN). These radars are dispersed across Australia — at Longreach in Queensland, Laverton in Western Australia and Alice Springs in the Northern Territory — to provide surveillance coverage of Australia's northern approaches.

- Radar data from these sensors is conveyed to the JORN Coordination Centre (JCC) within the Air Force's No 1 Radar Surveillance Unit (1RSU) at RAAF Base Edinburgh in South Australia. 1RSU is tasked by higher headquarters to operate the JORN capability on a daily basis.

- JORN does not operate on a 24 hour basis except during military contingencies. Defence's peacetime use of JORN focuses on those objects that the system has been designed to detect, thus ensuring efficient use of resources.

- The JORN radars have an operating range of 1000-3000km, as measured from the radar array. Figure 2 depicts the locations of the three OTHR systems and the JCC, and highlights the coverage of each radar. Of note, the Alice Springs and Longreach radars cover an arc of 90 degrees each, whereas the Laverton OTHR coverage area extends through 180 degrees.

Figure 2: JORN radar locations and coverage

What can JORN do?

- JORN is expected to detect air objects equivalent in size to a BAe Hawk-127 aircraft or larger and maritime objects equivalent in size and construction to an Armidale-class patrol boat or larger.

- On any given day JORN may be affected by the following:

  State of the ionosphere. The ionosphere is the upper part of the atmosphere extending from 75 to 450 km above the Earth's surface that consists of particles that have been ionised by solar radiation emitted by the Sun. The state of the ionosphere depends on the level of solar activity. Other more localised phenomena also affect the stability and/or structure of the ionosphere, and t is the combination of these phenomena and solar events which determines the quality of ionosphere support for OTHR operations. The most significant factors affecting such support include:

  - the 11 year solar cycle;
  - solar disturbances (i.e. flares and coronal mass ejections);
  - meteors;
  - geomagnetic activity;
  - ionospheric disturbances; and
  - ionospheric variations throughout the day/night.

  Environmental conditions. The natural environment can also limit the effectiveness of OTHR in detecting specific objects, namely:

  - rough seas and winds can cause increased radar clutter making the detection of maritime vessels extremely difficult; and
  - lightning associated with thunderstorms can cause localised ionospheric changes.

- Additionally, the probability of detecting a particular object is dependent on the object's characteristics and/or behaviour.

– **Object characteristics.** For an aircraft or maritime vessel to be detected, it must possess a radar reflective (metal) surface of sufficient size so that sufficient **HF** radar energy is reflected back along the transmission path to the JORN receiver. For example:

* it is highly improbable that an OTHR will detect a small wooden boat
* OTHR is very unlikely to detect a hot air balloon or a glider constructed largely of wood

– **Object behaviour.** OTHR systems operate on the Doppler principle, where an object will only be detected if its motion toward or away from the radar is different from the movement of its surroundings. Objects travelling tangentially to an OTHR are therefore unlikely to be detected by that radar.

–

JORN's history and development

- The first OTHR was installed at Alice Springs in 1974 under a Defence Science and Technology Organisation (DSTO) research program. Under Project Jindalee, the Alice Springs radar was upgraded from its original design and commenced further trials in early 1982. It detected its first ship in early 1983 and its first aircraft was automatically tracked in early 1984.
- Project Jindalee finished in December 1985.

. The decision to develop JORN as a Defence asset had its beginnings in February 1985 when the Minister for Defence, Kim Beazley, commissioned an analysis of Australia's defence planning seeking recommendations for future developments. This analysis, by Paul Dibb was published in March 1986 and recommended that Australia abandon the remaining elements of the forward defence policy and concentrate its military resources on the geographic areas relevant to defending the country and its economic interests from direct attack. Dibb recommended that Australia's military posture be based on a strategy of denying aggressors the ability to attack the country. This was to be achieved through using a layered defence of over-the-horizon radar, patrol aircraft and maritime strike aircraft to protect Australia's approaches.

- At the time of Dibb's report, the experimental OTHR at Alice Springs was in operation and proved that 'modern technology in the form of OTHR offers the prospect for the first time of broad-area real-time surveillance of our air and sea approaches out to 1500 nautical miles.' Dibb's review recommended that additional resources be applied to the Jindalee OTHR program to further

exploit this promising technology and added that there was a strong case for considering at least two further OTHRs.

- His recommendation to invest in OTHR research and acquire an operational system was adopted in the 1987 Department of Defence White Paper, *The Defence of Australia',* which stated that the Government has given high priority to the design and development of this [OTHR] network, based on the Australian designed Jindalee experimental radar. The OTHR network will be a basic element of a national system for air defence and airspace control.' The paper identified the Government's intention to acquire three OTHRs.

- Based on the 1987 Defence White Paper, Joint Project 2025 (JP2025) was initiated to build a further two OTHRs. In 1991, a contract was awarded to Telstra, in cooperation with GEC-Marconi, to build two operational OTHRs that would form JORN. After considerable project difficulties, responsibility for the project moved to Lockheed Martin and Ten ix (who formed the RLM Group) in 1997, and in 1999 1RSU moved from Alice Springs to RAAF Base Edinburgh to remotely operate the Alice Springs OTHR from the JORN Coordination Centre. In 2003, RLM Group delivered two JORN OTHRs to the Australian Defence Force. These radars, along with the Alice Springs radar, comprise JORN in its current form. During the period where the JORN project was unable to deliver an operational system, the Alice Springs radar continued to receive a number of upgrades based on DSTO research and development.

- JP2025 Phases 3 and 4 commenced in 2003 to provide incremental upgrades to the newly delivered radars and concluded in 2007.

- JORN is currently undergoing a capability upgrade under JP2025 Phase 5. This project will incrementally deliver a number of capability enhancements to the current JORN radars located at Longreach and Laverton, and will compliment upgrades delivered under Phases 3 and 4 to bring these radars up to the current technological specification of the OTHR at Alice Springs. Phase 5 will also integrate the Alice Spring OTHR into the Jindalee Operational Radar Network.

- The capability upgrade under JP2025 Phase 5 is based on the specifications originally described in the 1987 Department of Defence White Paper, 'The Defence of Australia'.

Appendix 6: Overseas efforts to build OTHR prior to Jindalee

SOVIET UNION

"Engineers in the Soviet Union are known to have developed what appears to be the first operational OTH system in 1949, called VEYER. However, little information on this system is available in western sources, and no details of its operation are known. It is known that no further research was carried out by Soviet teams until the 1960s and 70s" [70] [71].

MADRE (Magnetic Drum Radar Equipment)

The United States Navy Research Laboratories built a prototype OTHR installation called MADRE at Chesapeake Bay in the late 1950s. "….then classified work proceeded to demonstrate ionospheric stability and, towards the end of 1961, resulted in the first OTHR detections of air targets" [72]. Targets were detected at ranges up to 3700 km.

MADRE (Magnetic Drum Radar Equipment), Chesapeake Bay, United States, 1961. *Image: US Naval Research Laboratory.*

[70] Wikipedia. Over-the-horizon Radar. Updated 3 April 2016. Downloaded 19 April 2016.
[71] Frissall and Hockersmith.2008.page 3.
[72] Sinnott D H. The development of Over-the-horizon Radar in Australia. Defence Science and Technology Organisation (*DSTO)*, Australian Department of Defence. Bicentennial History Series. 1988. ISBN 0 642 13561 4. Page 4.

COBRA MIST

Cobra Mist came out of the MADRE project and commenced in 1964 and was a joint Anglo-American experimental project. The intention was to build an operational station in Turkey however after work had commenced the Turkish Government decided it did not want the base on its territory. The project was moved to the East coast of England and was located at Orford Ness, Suffolk. This station was completed in 1971 however it experienced serious unexplained interference problems, the cause of which could not be determined. The project was abandoned in 1973 without having achieved operational success [73].

Cobra Mist OTHR station, Orford Ness, Suffolk, England. Image dates from 2010 when the station was being used by the BBC Overseas Service. *Image: Wikipedia, Cobra Mist.*

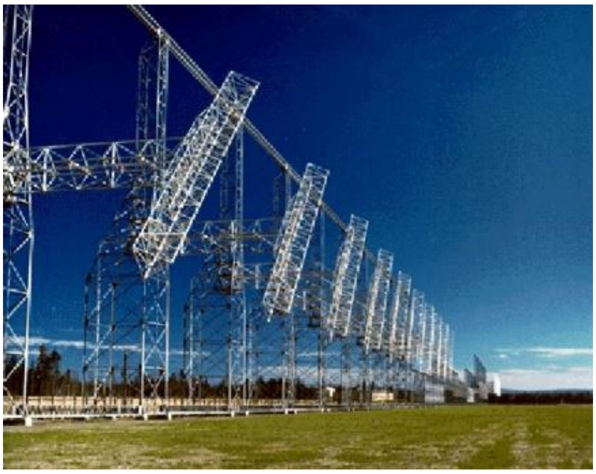
[73] Wikipedia. Cobra Mist. Updated 4 April 2016. Downloaded 19 April 2016. Page 1.

Appendix 7: Operational OTHR in other countries [74]

US Air Force

The USAF Rome Laboratory had the first complete success with their AN/FPS-118 OTH-B. A prototype with a 1 MW transmitter and a separate receiver was installed in Maine offering coverage over a 60 degree arc between 900 and 3,300 km [range]. This was completed circa 1970. A permanent transmitting facility was then built at Moscow Air Force Base, Maine and a receiving facility at Columbia Falls Air Force Base, Maine and an operational centre between them in Bangor, Maine. The coverage could be extended with additional receivers, providing for complete coverage over a 180-degree arc (each 60 degree portion known as a "sector").

United States Air Force AN/FPS-118 Receiver Station at Moscow Air Force Base [75].
Image: www.fas.org.



United States Air Force AN/FPS-118 Receiver Station at Moscow Air Force Base [76].
Image: www.fas.org.

[74] Wikipedia. Over-the-horizon Radar. Last updated 3 April 2016. Downloaded 21 April 2016.
[75] Note poor image quality due to small file.
[76] Ibid.

General Electric Aerospace was awarded the development contract, expanding the existing east coast system with two additional sectors, while building another three-sector system on the west coast, a two-sector system in Alaska (circa 1991-1992), and a one-sector system facing south. In 1992 the Air Force contracted to extend the coverage 15 degrees clockwise on the southern of the three east coast sectors to be able to cover the southeast U.S. border. Additionally, the range was extended to 3,000 miles (4,800 km), crossing the equator. This was operated 40 hours a week at random times. Radar data were fed to the U S Customs/Coast Guard C3I Centre, Miami; Joint Task Force 4 Operations Centre, Key West; U.S. Southern Command Operations Centre, Key West and U.S. Southern Command Operations Centre, Panama [77].

With the end of the Cold War, the influence of the two senators from Maine was not enough to save the operation and the Alaska and southern-facing sites were cancelled, the two so-far completed western sectors and the eastern ones were turned off and placed in "warm storage," allowing them to be used again if needed. By 2002, the west coast facilities were downgraded to "cold storage" status, meaning only minimal maintenance was performed by a caretaker.

Research was begun into the feasibility of removing the facilities. After a period of public input and environmental studies, in July 2005 the U.S. Air Force Air Combat Command published a "Final Environmental Assessment for Equipment Removal at Over-the-Horizon Backscatter Radar - West Coast Facilities". A final decision was made to remove all radar equipment at the west coast sector's transmitter site outside Christmas Valley, Oregon and its receiver site near Tulelake, California. This work was completed by July 2007 with the demolition and removal of the antenna arrays, leaving the buildings, fences and utility infrastructure at each site intact.

US Navy

The United States Navy created their own system, the AN/TPS-71 ROTHR (Relocatable Over-the-Horizon Radar), which covers a 64 degree wedge-shaped area at ranges from 500 to 1,600 nautical miles (925 to 3,000 km). ROTHR was originally intended to keep track of ship and aircraft movement over the Pacific, and thus allow coordinated fleet movements well in advance of an engagement. A prototype ROTHR system was installed on the isolated Aleutian Island of Amchitka, Alaska, monitoring the eastern coast of Russia, in 1991 and used until 1993. The equipment was later removed into storage.

The first production systems were installed in the test site in Virginia for acceptance testing, but were then transitioned to counter the illegal drug trade, covering Central America and the Caribbean. The second production ROTHR was later set up in Texas, covering many of the same areas in the Caribbean, but also providing coverage over the Pacific as far south as Columbia. It also operates in the anti-drug trafficking role. The third, and final, production system was installed in Puerto Rico, extending anti-drug surveillance past the equator, deep into South America.

[77] Federation of American Scientists (FAS).AN/FPS-118 Over-the-horizon Backscatter (OTH-B) Radar. http://www.fas.org/nuke/guide/usa/airdef/an-fps-118.htm

USSR/Russia

The Soviets had also studied OTH systems starting as early as the 1950s [78]. Their first experimental model appears to be the VEYER (Hand Fan) that was built in 1949. The next serious Soviet project was DUGA-2 [79] [80], built outside Nikolayev on the Black Sea coast near Odessa. Aimed eastward, DUGA-2 first ran on 7 November 1971, and was successfully used to track missile launches from the Far East and Pacific Ocean to the testing ground on Novaya Zemlya.

This was followed by their first operational system DUGA-3 known in the West as STEEL YARD [81] [82] which first broadcast in 1976. Built outside Gomel, near Chernobyl, Ukraine, it was aimed northward and covered the continental United States. Its loud and repetitive pulses in the middle of the shortwave radio bands led to it being known as the "Russian Woodpecker" by amateur radio (ham) operators. The Soviets eventually shifted the frequencies they used, without admitting they were even the source, largely due to its interference with certain long-range air-to-ground communications used by commercial airliners. A second system was set up in Siberia, also covering the continental United States, as well as Alaska.

Russian DUGA-3 OTHR Receiver of circa 1976 showing the massive size of the structures.
Image: Wikipedia.

[78] This date appears to be inconsistent with the 1949 date for construction of their first system in the following line.

[79] Wikipedia. Duga-1 and Duga-2. Last Updated 2 Feb 2014. Downloaded 22 April 2016.

[80] Pike John. Steel Yard OTHR. Retrieved 8 April 2010. Last update 1 December 2015. www.global.security.org

[81] Global Security. www.globalsecurity.org http://www.globalsecurity.org/wmd/world/russia/steel-yard.htm

[82] Wikipedia. Duga radar. Last updated 16 April 2016. Downloaded 22 April 2016.

Looking up through the complex antenna array of the Russian DUGA-3 Receiver of circa 1976 from ground level. ***Image: Wikipedia.***

In early 2014, the Russians announced a new system, called 'Контейнер' [KONTAYNER] [83] [84] that is designed for a range or over 3000 km. This radar is thought to be the type termed 29B6. It is understood that this radar was turned on in December 2013.

The Kolkino [85] radar station, using the first modernized 29B6 radar [86], is able to track aerial targets flying as far away as Denmark. Earlier the radar had a research role only, and even if full operational capability is expected within 2 years, the new system is already keeping an eye on what flies west of the Russian border.

Another 29B6 radar should be installed in the far eastern Russian territories, achieving operational status in 2018.

The radar is made of 150 antenna masts, data transmission systems, transmitters and receivers, power station and control building. The peculiarity of the system is that it is able

[83] Wikipedia. Kontayner radar. Last updated 12 November 2015. Downloaded 22 April 2016.
[84] Diario SWL 15-56578 Antonio. 29B6: Russian FMP OTH Radar KONTAYNER. Downloaded 22 April 2016.
[85] Kolkino is in Mordovia, a region of Russia about 480 km South East of Moscow. The radar receiver station is located at 53.9841 degrees N, 43.8427 degrees E amongst farmland. The antenna array points roughly at London at a range of exactly 3000 km.
[86] Wikipedia. 29B6 Kontayner OTH Radar. Last updated 22 April 2016. Downloaded 2 May 2016.

to detect both high altitude targets, such as ICBMs (Inter Continental Ballistic Missiles), as well as low altitude flying air traffic, at very long distances, well beyond the line of sight.

Based on the Russian claims reported by Defence24.pl, any aircraft with a radar cross section comparable to the one of a Cessna light plane would be detected by the new radar, even if it is flying at low altitude. Even a fighter jet taking-off in the Netherlands could be seen by the new surveillance station!

Provided technical specifications are confirmed, Russia will soon be able to monitor almost everything flying over eastern Europe, and beyond [87].

Russian KONTAYNER OTHR Receiver recently commissioned (probably December 2013).

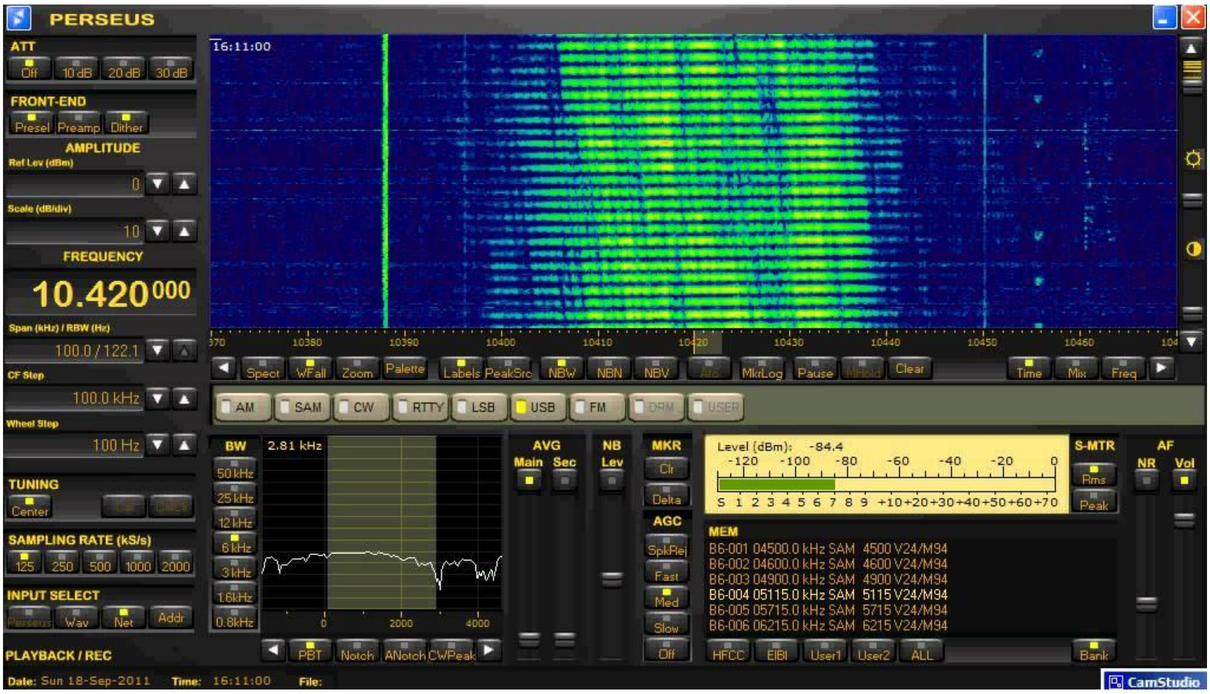
Image: The Aviationist.

France

The French have developed an OTH radar called NOSTRADAMUS during the 1990s [NOSTRADAMUS stands for New Transhorizon Decametric System Applying Studio Methods (French: *nouveau système transhorizon décamétrique appliquant les méthodes utilisées en studio*).] In March 1999 the OTH radar NOSTRADAMUS was said to have detected two Northrop B2 Spirit aircraft flying to Kosovo. It entered service for the French army in 2005, and is still in development. It is based on a star shaped antenna field, used for emission and reception (monostatic), and able to detect every aircraft at a range of more than 2,000 kilometres, in a 360 degree arc. The frequency range used is from 6 to 30 MHz.

[87] Siminski Jacek. The Aviationist. 12 December 2013.

Nostradamus Antenna Array. *Image: www.fraktail.biz.*



Nostradamus Receiving Panel. Image: source unknown.

Launched officially in 2009, the French STRADIVARIUS Research Project
[88] STRADIVARIUS research project developed a new over-the-horizon radar (High Frequency Surface Wave Radar – HFSWR) capable of monitoring maritime traffic up to 200 nautical miles offshore. A demonstration site is operational since January 2015 on the French Mediterranean coast to showcase the 24/24 7/7 capabilities of the system that is now offered for sales by DIGINEXT.

China

A number of OTH-B and OTH-SW radars are reportedly in operation in China. Few details are known of these systems. However, transmission from these radars causes much interference to other international licensed users.

One set of Chinese OTH-B radars is found on Google Maps for the Transmitter [89] and Receiver [90] by following the links in the footnotes.

Iran

Iran is working on an OTH radar called SEPEHR [91] with a reported range of 3,000 kilometres. It is now on operational status.

Iranian SEPEHR OTHR system. This recent system has the transmitter and receiver on the same site and has a 360 degree view. ***Image: Wikipedia.***

[88] Polemer Mediterranee. Stradivarius. http://en.polemermediterranee.com/DAS-Projets/Maritime-Safety-and-Security/Surveillance-and-maritime-intervention/STRADIVARIUS

[89] Link to Google Maps image of Transmitter Site near Wenzou, south of Shanghai in China transmitter

[90] Link to Google Maps image of Receiver Site near Wenzou, south of Shanghai in China receiver.

[91] Wikipedia. Sepehr (radar). Last updated 5 July 2015. Downloaded 22 April 2016.

Appendix 8: Manufacturer's Brochures on OTH Radar Receivers

ADVANCED DIRECT DIGITAL RECEIVER

BAE SYSTEMS AUSTRALIA

BAE SYSTEMS

DIRECT DIGITISATION OF THE HF SPECTRUM FOR HIGH-PERFORMANCE OTHR, SOUNDERS AND INTELLIGENCE GATHERING

- **Direct digitisation for wideband acquisition and analysis of the HF spectrum**
- **Wideband channel and multiple narrowband channels**
- **Exceptional wideband performance**
- **Analogue pre-conditioning**
- **Unrivalled signal dynamic range**
- **GigE interface**
- **Easy to use**

BAE Systems Australia's Advanced Direct Digital Receiver (DDRx) is designed

to support demanding HF radar and intelligence-gathering applications.

This receiver is the culmination of three generations of digital receiver development, to meet the increasing expectations of

HF spectrum users.

HF spectrum users require the detection and processing of minute energy returns in the presence of large intercontinental broadcast signals, coupled with the ability to accurately measure the time at which signals are received.

The receiver is housed in a half-width, one rack unit case. The standard configuration provides a single concurrent wideband with four narrowband configurations providing multiple channels with exceptional dynamic range. These channels are implemented

in firmware, and alternate channel configurations are also available.

The receiver uses analogue filtering to allow conditioning of the signal prior to the A/D converter.

The receiver can be directly connected to a commercial PC via GigE.

The DDRx system has been designed for online, real-time processing. Provision is made for an external timing reference, which allows synchronous deployment of multiple systems in an array configuration. The external timing reference also allows geographically separated receivers to be synchronised using GPS receivers.

The receiver is also capable of running stand-alone using an internal oscillator.

The DDRx is used in experimental radar systems and operational sounder systems, providing unrivalled wideband performance and ease of use.

SPECIFICATIONS

Frequency range: 5 to 35 MHz
(1 to 45 MHz optional) Noise figure: <10 dB Attenuation: 0 to 62 dB

Pre-selection filters: 4

Internal memory: 64 M samples Narrowband channels: Typically 4

- **Dynamic range: 148 dB**
- **Programmable BW: 7.5 to 250 kHz**
- **Frequency resolution: <25 MHz Wideband channel:**
- **Dynamic range: 90 dB**
- **Programmable BW: 0.2 to 4.25 MHz ADC channel:**
- **Dynamic range: 105 dB**
- **Bandwidth: 50 MHz Data interface: GigE**

FOR MORE INFORMATION CONTACT:
BAE Systems Australia Taranaki Road
Edinburgh Parks EDINBURGH SA
5111

PO Box 1068 Salisbury SA 5108
Telephone +61 (0)8 8480 7150
Fax +61 (0)8 8480 8800
Email au.hfproducts@baesystems.com www.baesystems.com/australia

CUSTOMER SUCCESS STORY

BAE SYSTEMS AUSTRALIA - WORLD LEADING DEVELOPER OF HF RADAR TECHNOLOGY, BAE SYSTEMS AUSTRALIA USES ALTIUM DESIGNER TO CREATE CUTTING-EDGE SIGNAL SYSTEMS FOR AUSTRALIA'S UNIQUE OVER THE HORIZON SURVEILLANCE RADAR.

BAE SYSTEMS

The Need

Monitoring Australia's enormous northern coastline is a key element in the country's national security program, but the huge area involved creates the challenge of detecting objects beyond the horizon. The Australian Defence Force's (ADF) Jindalee Over The Horizon Radar (OTHR) system, near Alice Springs in central Australia, overcomes the normal range limitations caused by the curvature of the earth by bouncing signals off the ionosphere using a series of antennas that stretch over 3.4 kilometres.

" Altium Designer allows us to create advanced high-frequency digital radar receivers and signal processors within budget and on-time. With the ongoing development of high-frequency radar systems we rely on Altium Designer to help us utilize the latest design techniques and technologies. "

Jeff Robinson, Principal Technical Officer, BAE Systems Australia

Leading global defence company and user of Altium Designer, BAE Systems Australia supports the ongoing development of the super-sensitive Jindalee radar with advanced receiver and signal processing systems that help to extend the capabilities of the ADF's Jindalee Operational Radar Network (JORN). Creating these systems requires that BAE Systems remain at the forefront of HF radar technology, including the development of RF and high-speed data processing systems.

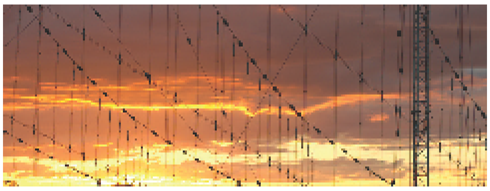
The Challenge

With typical HF projects requiring up to 10-layer FR4 boards that comply to strict performance goals in both the analog and digital domain, BAE Systems' engineers require advanced tools and design systems for the successful development of the OTHR subsystems.

BAE Systems recent Advanced Digital HF Radar Receiver project, with a concept-to-completion time of just 6 months, involved the development of five multilayer boards featuring high-performance linear amplifiers and RF filters, high-speed A/D converters plus Gigabyte Ethernet and USB2 I/O services. Featuring SMT devices on both sides of the boards along with the complex DC subsystems required to meet receiver performance goals, developing the high-density board designs required high levels of engineering expertise plus a powerful and comprehensively-featured PCB development system.

The Solution

Since its inception around six years ago, the BAE Systems HF radar development group has used Altium Designer for board development, progressing through an upgrade path to its current Altium Designer 6 licences. The resulting increase in features and performance of the design solution during this time has kept BAE Systems' engineers at the forefront of board design technology and given them the capabilities needed to develop the highly sophisticated board designs required to enhance the OTHR system.



Further to this, Altium Designer's unified board-level design capabilities, such as powerful Signal Integrity analysis, differential pair support and automated FPGA pin optimization, has improved project time frames while ensuring that designs perform as expected early in the development cycle. In an environment where cutting-edge performance is a core design criteria, Altium Designer's unified design solution provides BAE Systems with the sophisticated board development capabilities required to meet its goals.

CUSTOMER SUCCESS STORY

BAE SYSTEMS AUSTRALIA - WORLD LEADING DEVELOPER OF HF RADAR TECHNOLOGY, BAE SYSTEMS AUSTRALIA USES ALTIUM DESIGNER TO CREATE CUTTING-EDGE SIGNAL SYSTEMS FOR AUSTRALIA'S UNIQUE OVER THE HORIZON SURVEILLANCE RADAR.

BAE SYSTEMS

The Need

Monitoring Australia's enormous northern coastline is a key element in the country's national security program, but the huge area involved creates the challenge of detecting objects beyond the horizon. The Australian Defence Force's (ADF) Jindalee Over The Horizon Radar (OTHR) system, near Alice Springs in central Australia, overcomes the normal range limitations caused by the curvature of the earth by bouncing signals off the ionosphere using a series of antennas that stretch over 3.4 kilometres.

" Altium Designer allows us to create advanced high-frequency digital radar receivers and signal processors within budget and on-time. With the ongoing development of high-frequency radar systems we rely on Altium Designer to help us utilize the latest design techniques and technologies. "

Jeff Robinson, Principal Technical Officer, BAE Systems Australia

Leading global defence company and user of Altium Designer, BAE Systems Australia supports the ongoing development of the super-sensitive Jindalee radar with advanced receiver and signal processing systems that help to extend the capabilities of the ADF's Jindalee Operational Radar Network (JORN). Creating these systems requires that BAE Systems remain at the forefront of HF radar technology, including the development of RF and high-speed data processing systems.

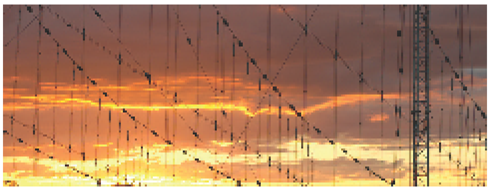
The Challenge

With typical HF projects requiring up to 10-layer FR4 boards that comply to strict performance goals in both the analog and digital domain, BAE Systems' engineers require advanced tools and design systems for the successful development of the OTHR subsystems.

BAE Systems recent Advanced Digital HF Radar Receiver project, with a concept-to-completion time of just 6 months, involved the development of five multilayer boards featuring high-performance linear amplifiers and RF filters, high-speed A/D converters plus Gigabyte Ethernet and USB2 I/O services. Featuring SMT devices on both sides of the boards along with the complex DC subsystems required to meet receiver performance goals, developing the high-density board designs required high levels of engineering expertise plus a powerful and comprehensively-featured PCB development system.

The Solution

Since its inception around six years ago, the BAE Systems HF radar development group has used Altium Designer for board development, progressing through an upgrade path to its current Altium Designer 6 licences. The resulting increase in features and performance of the design solution during this time has kept BAE Systems' engineers at the forefront of board design technology and given them the capabilities needed to develop the highly sophisticated board designs required to enhance the OTHR system.



Further to this, Altium Designer's unified board-level design capabilities, such as powerful Signal Integrity analysis, differential pair support and automated FPGA pin optimization, has improved project time frames while ensuring that designs perform as expected early in the development cycle. In an environment where cutting-edge performance is a core design criteria, Altium Designer's unified design solution provides BAE Systems with the sophisticated board development capabilities required to meet its goals.

www.altium.com Altium

92

[92] Altium Limited. www.altium.com.

SBIR Source [93]

HF Digital Receiver

OBJECTIVE

High Frequency (HF) Digital Receiver Design and Development for Next Generation Over the Horizon Radar (OTHR). The digital receiver will provide wideband HF data for multiband processing for radar detection and track performance improvements.

DESCRIPTION

Next Generation Over the Horizon Radar (OTHR) has the ability to provide wide area surveillance. The radar operates over the 6 - 28 MHz band. By refracting off the ionosphere, the radar can detect targets at ranges from 1000 to 3000 km. Current generation OTHR use linear arrays with analog receivers. A next generation system is expected to have two dimensional (2D) arrays (narrow beam in both elevation and azimuth), arbitrary waveform generator/power amplifier at every transmit element, and digital receivers at every receive element. This fully digital array will have significant capability, including the ability to function in a Multiple Input Multiple Output (MIMO) radar mode.

The objective of this effort is to design and develop a large instantaneous bandwidth receiver for the next generation fully digital beamforming HF radar. The receiver design should include an analog front-end processing, analog-to-digital conversion (ADC), digital down conversion and control interface. Each section will be isolated from each other to minimize spurs and signal interferences. A very high dynamic range is needed for a low noise figure in the signal processing path to provide the radar with the capability to resolve weak targets in the presence of clutter and interference.

The analog front end will include preamps, attenuators, band-pass filters, pre-selection filters, ADC driver amplifiers, and anti-aliasing filters. Input Voltage Standing Wave Ratio (VSWR) should be less than 2:1, with a noise figure around 7 dB typically. The pre-selection filters should be programmable. The gain of the analog section shall be sufficient that the noise of the external environment at no attenuation shall dominate the overall receiver noise level. The design will maximize the dynamic range.

The analog to digital conversion shall be sampled at a minimum of 100 MHz and synchronized to an external clock source. The design should allow the capture of raw analog-to-digital (A/D)

---

[93] https://sbirsource.com/login

output data, stored in onboard memory buffers, with the ability to send the information to a host computer.

Digital Down Conversion (DDC) shall allow the ability to provide both narrowband and wideband channels simultaneously. The receiver will be able to delay the sampling start relative to the sync source. The DDC internal data word size shall be greater than 24 bits for narrowband and 16 bits for wideband to meet the desired dynamic range requirements.

A control interface will be provided that allows the receiver to be commanded during normal radar operation and local tests.

PHASE I

The contractor will work with the HF technical community to define performance requirements for their digital receiver design. The design will be suitable for incorporation into an operational testbed. High risk elements will be identified and mitigation strategies outlined.

PHASE II

The contractor will build prototype HF receiver(s). The receiver will be tested both by the contractor as well as by a government team. Conducted tests will quantify performance metrics such as dynamic range and spurious signals. The production methods and cost of the design will be quantified. Results will be documented in a final report.

PHASE III

DUAL USE COMMERCIALIZATION: Military Application: There is increased interest in the HF spectrum for radar and communications. HF radar and communication systems are migrating to HF digital receivers to take advantage of the improvements from enhanced signal processing. Commercial Application: There is a broad base of commercial users in the HF spectrum, including HAM operators, environmental diagnostics, surface wave oceanic radars, etc. An affordable digital receiver would be attractive to all parties.

REFERENCES

1. Frazer, Gordon, "Forward-based receiver Augmentation for OTHR", Radar Conference 2007, Pages 373-378.
2. Fabrizio, G.; Colone, F.; Lombardo, P.; Farina, A.; "Adaptive beamforming for High Frequency Over the Horizon Passive Radar", Radar, Sonar & Navigation, IET, Vol 3, Issue:4, 2009, Pages 384-405.
3. Pearce, T.H.; "The application of digital receiver technology to HF Radar", HF Radio Systems and Techniques, 1991, Fifth International Conference on, Pages 304-309.
4. Oscarsson, C.F.A.; "Digital HF Receiver", Radio Receivers and Associated Systems, 1995, Sixth International Conference on, 1995, Pages 47-51.

OFFICIAL SOLICITATION

This material is pulled from the official solicitation released by the government. For official updates, solicitation rules and regulations, and submission instructions, please consult the official documentation.

Appendix 9: Specification for Jindalee B System [94]

Name of System	**Jindalee B**
Commissioning Date	April 1982
Operating Frequency	HF 5-35 MHz
Monostatic/Bistatic	Bistatic
Transmitting Power	560 kW peak, 158 kW
Transmitter Antenna Gain	21 dB
Receiver Antenna Power Gain	32 dB
Coherent Integration Time	17 dBs
Angular Resolution	0.5 degrees
Range Resolution	20 km
Detection Range	1000-3000 km

[94] Liu Bin-Yi. HF Over-the-horizon Radar System Performance Analysis. Naval Postgraduate School, Monterey, California, United States of America. September 2007. Thesis. Page 43.

Change Control

CHANGE CONTROL			
VERSION 1	18 APRIL 2016	1019 WORDS	DRAFTING STARTED
VERSION 2	19 APRIL 2016	3311 WORDS	DRAFTING
VERSION 3	20 APRIL 2016	4129 WORDS	DRAFTING
VERSION 4	21 APRIL 2016	7411 WORDS	DRAFTING
VERSION 5	22 APRIL 2016	7711 WORDS	DRAFTING
VERSION 6	23 APRIL 2016	8529 WORDS	DRAFTING
VERSION 7	25 APRIL 2016	9990 WORDS	DRAFTING
VERSION 8	27 APRIL 2016	12024 WORDS	DRAFTING
VERSION 9	28 APRIL 2016	13840 WORDS	CREATION OF REFERENCE LIST FROM FOOTNOTES AND ADDITION OF TEXT FOR INTERPRETATION
VERSION 10	29 APRIL 2016	15358 WORDS	DRAFTING AND ADD APPENDIX 8
VERSION 11	2 MAY 2016	15695 WORDS	ADDED TO RUSSIAN ENTRY APPENDIX 7
VERSION 12	9 MAY 2016	15927 WORDS	ADDED APPENDIX 9 & FOUR ADDITIONAL IMAGES
VERSION 13	16 MAY 2016	16130 WORDS	CHECK READ
VERSION 14	29 JUNE 2016	16130 WORDS	SPELLING CORRECTION FINAL TO FINALLY, P26, PARA 1, ADDITION OF FOOTNOTE 1 TO INTRODUCTION